Enhancing Existing Health and Safety Processes in Public Sector Construction Projects within Saudi Arabia using Building Information Modelling Approaches

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Abstract

Current statistics on Health and Safety (H&S) outcomes the Kingdom of Saudi Arabia (KSA) public construction sector demonstrate the need for academic and practical assessment of the current environment for the purpose of improving outcomes. Even though the construction public sector in Saudi Arabia has been rapidly expanding, the H&S record of this industry remains considerably poor, as evidenced by the rising figures of injuries and deaths. The purpose of this research is to assess the current use of H&S technologies and, therefore, possibilities for the use of building information modelling (BIM) in the industry. The research aims to enhance H&S management in Saudi public sector construction projects by exploring integrated approaches to project design and delivery using BIM-based technologies and processes

This research uses a mixed method approach to assess the current H&S environment to develop a framework suitable for the unique environment aimed at improving the current outcomes. The data collected through a survey and interviews with subject matter experts has been analysed to outline the major issues facing the implementation of innovative technologies to improve current business processes and provide a roadmap to enhance the predominant H&S policies and activities in Saudi Arabia. Challenges identified through these efforts include the Saudi environment as having high levels of fragmentation, a low skilled, multilingual and multi-ethnic workforce and inefficient use of BIM technologies being made.

Based on these findings, a framework, which incorporates BIM to include automated hazard identification and correction during design and during construction, has been developed. The framework is initially devised based on a synthesis of the literature and further refined based on findings from questionnaires. The result of this research is the identification of 18 factors impacting H&S. The framework is developed and validated using interpretive structural modelling (ISM). Through these methods, the key driving factors for improving H&S outcomes in the public construction sector in KSA are identified. Among these, better enforcement of regulations and laws is identified as the key factor needed for improving outcomes. The study concludes with a discussion of the applications of the proposed framework and recommendations for future research. Specifically, this research advocates for the inclusion of BIM technologies in H&S frameworks as a method of addressing the specific challenge of communicating with a predominately migrant workforce. This new approach for H&S analysis during construction focuses on the integration of construction simulation, 3D/4D/5D construction management and safety analysis through the incorporation of technology for both planning and communication.

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Acronyms and Abbreviations

2D	Two Dimensional
3D	Three Dimensional
4D	Four Dimensional
BCIM	Building Construction Information Model
BIM	Building Information Modelling
CAD	Computer-aided Design
DBB	Design-bid-build model
ECTP	European Construction Technology Platform
GCC	Corporation Council for the Arab States of the Gulf
GOSI	General Organisation for Social Insurance in Saudi Arabia
H&S	Health and Safety
ICT	Information and Communication Technology
ILO	International Labour Organisation
ISM	Interpretive Structural Modelling
KPI	Key Performance Indicators
KSA	Kingdom of Saudi Arabia
OOMT	Objective oriented Modelling Technology
OPEC	Organisation of the Petroleum Exporting Countries
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
RFID	Radio Frequency Identification
RQ1	Research Question 1
SPSS	Statistical Package for the Social Sciences
SSIM	Structural Self-Interaction Matrix

Chapter 1. Introduction

1.1 Introduction

This chapter provides a discussion of the research gap relating to the context of health and safety (H&S) barriers in the public sector construction industry in the Kingdom of Saudi Arabia (KSA), as well as an analysis of related variables and considerations. A detailed literature review is introduced to link all the factors at play in a complex and perhaps interdependent series of problems and issues that may be discovered and explored in the construction industry in KSA. A background investigation is used to identify gaps in the literature, from which the research design is developed and presented, including the aims, objectives, research questions, data collection and analysis methodologies. The thesis structure is then presented.

1.2 Research Background

The geographic focus of this study is KSA, which is the second largest Arab country (after Algeria) and the largest in the Arabian Peninsula, with an area of 2,150,000 km^2, about one-quarter the size of the USA (World Factbook, 2016; see Figure 1-1). Originally part of the Ottoman Empire, KSA has eastern boundaries on the Arabian Gulf and western boundaries on the Red Sea coast. To the north it is bordered by Iraq, Jordan and Kuwait and to the south by Yemen, Oman and the United Arab Emirates. Qatar and Bahrain border the country to the east. Of the country's 28.83 million residents, 8 million are migrant workers, many of whom are from the developed world and are managers of global companies, but the majority are labourers from developing countries, particularly India and Pakistan. The KSA capital, Riyadh, lies on the central plateau and its second largest city is Jeddah, located on the Red Sea coast. It is primarily and geologically a desert environment, with three major deserts connected to the Sahara. The Rub'al Khali Desert—which translates as "the empty quarter" – is the largest continuous body of sand in the world, occupying the majority of the southeast of the country (World Factbook, 2016).

Historically, KSA was made up of several original tribal settlements and regions, two of which, Hejaz on the east coast and the most densely populated region, and Nejd on the central plateau

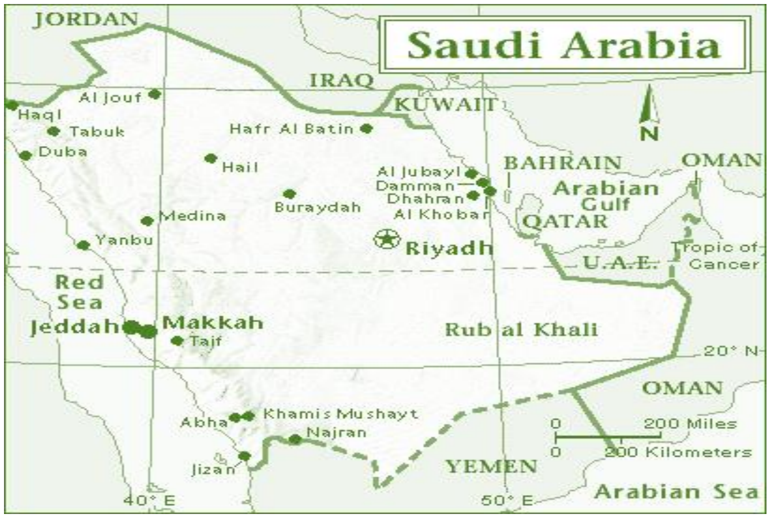

Figure 1-1:KSA map

and largely nomadic, were taken control of by the Saud dynasty in 1932, who were then declared monarchs (Saudi Embassy, 2016). KSA was, at this time, one of the poorest countries in the world and many of the inhabitants, particularly in the southeast, were nomadic and involved in inter-tribal and familial conflicts. However, in 1938, oil was discovered in the largely uninhabited desert region of the south and east, giving revenue not only to the newly established KSA but also to the countries bordering it. KSA is now the largest petroleum exporter in the world and holds 18% of global petroleum reserves (OPEC, 2013), making it one of the fastest-growing economies in the Middle East region (see Figure 1-2).

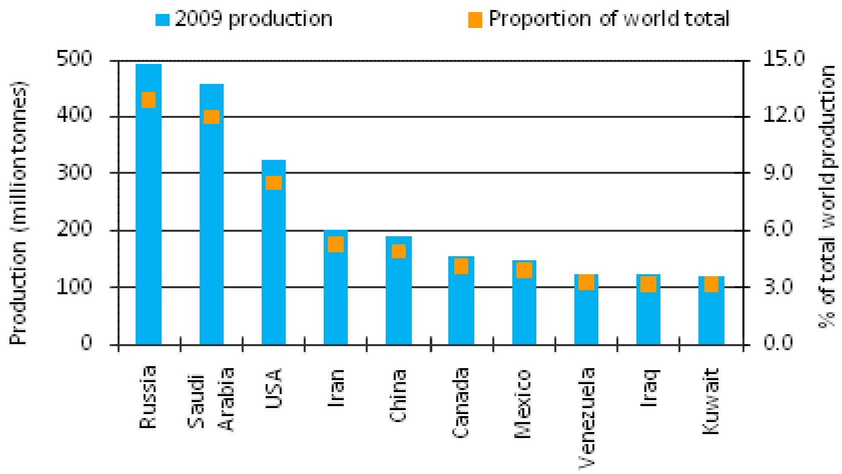

Figure 1-2:Oil production as a percentage of world total as of 2009 (Euromonitor International from BP Statistical Review of World Energy)

1.3 Key H&S Challenges in KSA Construction Industry

The construction industry in KSA is plagued by safety related accidents, ranging from minor trauma to major injuries and death (Alhaadir & Panuwatwanich, 2011). As of 2011, 3.5 million individuals were employed in the private sector construction workforce, accounting for 45.1% of the total construction workforce (Saudi Arabian Monetary Agency, 2013); this indicates that about 55% of KSA construction workforce are employed in the public sector. However, there is a lack of regulatory measures taken by government agencies to ensure construction safety in KSA (Alhaadir & Panuwatwanich, 2011). Accidents could have been prevented merely by implementing and following common safety policies and procedures. This lack of regulation, coupled with poor safety related training, leads to a high number of accidents (Alhaadir & Panuwatwanich, 2011).

As highlighted by Haupt and Smallwood (1999), actions and guidelines followed to decrease construction H&S hazards within developing countries are characteristically unsatisfactory. In the context of KSA as a developing country, there has been a growing trend for the provision of safe working settings. Despite this, KSA is still found lacking in aspects of H&S in the construction industry. While it is known that this industry is particularly dangerous and that accidents may occur in it, it is also known that there are safety precautions that can be taken to reduce the number of deaths and injuries occurring on construction sites. In KSA, 51% of all workplace accidents occur within the construction industry, a significant percentage for a single industry (Hamalainen & Saarela, 2006). The exact number of construction related injuries is difficult to ascertain for KSA, in that many injuries are not reported (Hamalainen & Saarela, 2006). This is often a consequence of poor enforcement and lack of regulations, as referenced above.

An examination of the literature indicates a prevalence of similar adverse H&S trends in construction industries across the world (e.g. Lingard & Rowlinson, 2005). According to the International Labour Organisation (ILO) statistics, an estimated 25%-40% of deaths in international occupational environments occur in the construction sector (ILO, 2005). Arndt et al. (2009) argue that in recent years, even though working conditions have been enhanced in a number of developed countries, some operations are still linked to a high risk of physical harm because of the physical tasks associated with the sector, such as lifting and carrying of heavy items and uncomfortable work positions, as well as the environment in which construction industry work is carried out; these include noisy conditions, vibration, dusty environments and weather impacts. Thus, the combination of physical labour and the hazardous environment in which it is performed likely contributes to workers' deteriorating health and lack of safety. Hence, It is clear that the construction industry in general could be described as hazardous.

There are established international guidelines, representing consensus on H&S in construction, which include a common set of regulations, requirements and other considerations in the area of H&S. Many international human rights documents also address H&S. For instance, ILO identifies the most basic but necessary guidance to all nations in regard to H&S in the construction sector (ILO, 1992):

> Regulation 2.1.1: The competent authorities should, on the basis of an assessment of the safety and health hazards involved and in consultation with the most representative organisation of employers and workers, adopt and maintain in force national laws or regulations to ensure the safety and health of workers employed in construction projects and to protect persons at, or in the vicinity of, a construction site from all risks which may arise from such site.

> Regulation 2.1.2: The national laws and regulations adopted in pursuance of paragraph 2.1.1 above should provide for their practical application through technical standards or codes of practice, or by other appropriate methods consistent with national conditions and practices.
>
> Regulation 2.1.3: In giving effect to paragraphs 2.1.1 and 2.1.2 above, each competent authority should have due regard to the relevant standards adopted by recognised international organisations in the field of standardisation (p. 5).

The essential components of H&S provisions on construction sites are, therefore, summarised as being guided by: 1) regulation in an awareness of hazard; 2) having a code of practice or technical standards established by law; and 3) provisions that are internationally applicable and adopted. The most important issue here is that they should be standardised within and across countries. All H&S practices throughout the world should be the result of international consensus as to exactly what standards should be adopted.

In the UK, H&S principles are enforced by the Health and Safety Executive (HSE), and its guiding principle for regulation is that those who create hazards are best placed to control them (HSE, 2013). This guidance emphasises a very simple understanding that risk management should be internally controlled by those aware of the risks a process creates and that if self-management were conducted responsibly through the industry, there would be no need for external intervention. It also contains the important factor that there should be a degree of trust towards the leaders of enterprises. In the USA, attention has recently been directed, as it has in many countries, to the establishment of a safety climate or a safety culture. This is, above all, built on the issues of communication throughout the industry, emphasising that documentation and information should be disseminated continually through signage and technology, as prescribed by internal H&S policies.

The organisation of safety procedures should start at the very top echelon of the industry with a top-down approach to management, but should include total and continual consultation with the workforce; and responsibility and accountability should be built in to all processes (Baxendale & Jones, 2000; Abudayyeh et al., 2006; Anton, 1989; Ng et al., 2005; Chaudhry et al., 2007). Safety culture – "shared beliefs, practices and attitudes that exist at an establishment" (Department of Labor, 2016) – is above all a training culture, but training should have rewards for those who learn best and operationalise what they have learned. Finally, safety culture emphasises that safety is an omnipresent concern held by all actors and in all departments. Zhang et al. (2002) summarise the above in their definition of 'safety culture':

> The enduring value and priority placed on worker and public safety by everyone in every group at every level of an organisation. It refers to the extent to which individuals and groups will commit to personal responsibility for safety; act to preserve, enhance and communicate safety concerns; strive to actively learn, adapt and modify (both individual and organisational) behaviour based on lessons learned from mistakes; and be rewarded in a manner consistent with these values. (Zhang et al. 2002, p. 3).

According to the USA Department of Labor (2016), there are sixteen attributes of building a strong safety culture to promote H&S in the workplace: 1) obtaining the buy-in of top management; 2) promoting continuous buy-in; 3) building trust; 4) conducting self-assessments using benchmarks; 5) providing initial training; 6) establishing a safety steering committee; 7) developing site-specific safety visions; 8) aligning the organisation to the safety vision; 9) defining and assigning specific roles; 10) developing an accountability system; 11) develop a safety measures system; 12) developing policies for rewards and recognition; 13) conducting awareness training, including a kick-off; 14) implementing process change, 15) continuously measuring, communicating and celebrating successes; and 16) providing on-going compliance support. These broad guidelines are suitable across all industries and countries, but given the high rate of injuries in the construction sector, are particularly needed to promote H&S in construction.

These sixteen attributes are listed to demonstrate the principal features of a well-organised company, tuned into a safety culture. However, it should be understood that in order for this to happen, external impositions of formal regulation might not be necessary. On the other hand, where an industry is unregulated or has regulations that are rarely applied, especially where there exists a multitude of beliefs and cultures in general, accidents are more likely. This very much describes the position in public construction sites in KSA, where multicultural and multilinguistic migrant workers with a low socioeconomic and educational level might not understand “the extent to which individuals and groups will commit to personal responsibility for safety”. In this case, along with other Arabian Gulf countries, the employment of these labourers, often uneducated and from poor rural communities in South Asia, working on temporary worksites might pose a challenge to the theory that within a company or an industry all employees can cooperatively create a safety culture in the construction industry. Safety considerations may be more of a priority for native employees in a more developed country, as these workers have a greater awareness of their contribution to the process, seek and can be offered promotion in a stable location, and are able to take up offers of training and welcome communicative approaches.

1.4 Research Rationale

The extant literature presents four issues relating to H&S in the construction industry in KSA: 1) the need to develop a performance measurement approach suited to the Saudi environment; 2) the need to understand better the perception of Saudi contractors; 3) the need for investigation into the potential of advanced information communication technology (ICT) in improving construction safety practices within KSA; and 4) the impact of advanced Building Information Modelling (BIM) tools to enhance construction H&S in the Saudi context needing further investigation. These four components are considered integral to improvement of H&S factors in the Saudi construction industry and, as so, are used to outline the research problem presented herein.

1.5 Research Questions

This research study is being undertaken to answer the following fundamental research questions relating to the overarching research problem of assessing the contextual phenomenon of H&S practices, including barriers to implementation, in KSA:

- What are the best practices in terms of H&S management in a broader context?
- What are the current practices in H&S in KSA construction sector? How do these practices compare to the best practices established in RQ1?

- What are the existing challenges in construction H&S performance management, according to public sector construction contractors in KSA?
- How is BIM currently used? How can BIM enhance the continuous improvement of H&S on construction sites?
- What are the key challenges in terms of BIM adoption for H&S within KSA context?

Using these research questions to develop the research design has provided the guide necessary to evaluate the safety concerns within the Saudi construction industry and allow for policy recommendations for the industry in terms of lowering H&S risks associated with it.

1.6 Research Aims and Objectives

The aim of this research is to look to enhance H&S management in Saudi public sector construction projects by exploring integrated approaches to project design and delivery using BIM-based technologies and processes. As such, the research objectives are:

- To explore the existing practice of H&S in public sector construction projects in KSA
- To identify the relationship between BIM and H&S in construction
- To develop an integrated framework for using BIM in construction to address safety issues in contractor organisations
- To test, evaluate and validate the framework developed through expert feedback
- To provide recommendations on best practice for H&S in public sector construction projects in KSA

1.7 Outline Research Methodology

The research design, developed from the research problem as presented in Section 1.3, dictated the methods used to collect data and answer the research questions, as well as to clarify the key steps in the research processes (Table 1-1). This study employs a mixed method study approach, combining aspects of both qualitative and quantitative data collection and analysis. Mixed method approaches “permit a more complete and synergistic utilisation of data than doing separate quantitative and qualitative data collection and analysis” (Wisdom & Creswell, 2013).

Data will be collected through questionnaires and interviews conducted with those working within the Saudi construction industry.

The research focused on KSA contracting organisations that are engaged in public sector construction projects and examined surely you mean “a sample of their employees in several major construction organisations. Specifically, the sample was selected from those contractor firms that are classified in the first or second category for buildings and roads, according to the contractor classification in the Saudi Ministry of Municipal and Rural Affairs (MOMRA 2014).

Table 1-1: Summary of key research objectives, research questions and outline methods

Objectives	Research Questions	Literature review	Survey	Interview	Interview (Validation
• To explore the existing practice of H&S in the public sector construction projects within KSA.	• What is best practice in terms of H&S management? • What are the current practices in H&S in KSA construction sector? How do these practices compare to the best practices established in RQ1? • What are the current practices in H&S in KSA construction sites? • What are the existing challenges in construction safety and health performance management, according to public sector construction contractors in KSA?	S	P	P	
• To identify the relationship between BIM and H&S in construction.	• How can BIM enhance the continuous improvement of H&S on construction sites? • What are key challenges in terms of BIM adoption for H&S within KSA context?	S	P	S	
• To develop the integrated framework for using BIM in construction and address safety issues in contractor organisations. • To validate the framework for using BIM in construction to address safety issues in contractor organisations. • To provide recommendations for best practice in public sector construction projects within KSA	• How benefits of construction safety framework are perceived by Saudi contractors?				P

S Secondary data P Primary data

1.8 Organisation of Thesis

Chapter 1 In this chapter, the research background, rationale, aims and objectives, and key research questions are provided, along with a brief outline of the research methodology. In addition, an overview of KSA is given with specific reference to its construction industry. A number of challenges encountered by construction workers within KSA are identified and the rationale behind this research is explained.

Chapter 2 introduces the literature that is relevant to the study, focusing on a review of H&S management practices within KSA.

Chapter 3 examines the literature relating to BIM in the construction industry in developed countries, as well as the relationship between BIM and H&S in construction. The chapter highlights the use of visualisation to promote identification of hazards in the design phase and eventual construction, including the tools used, to enhance H&S, particularly in KSA. The majority of the literature is examined in terms of the use of key performance indicators (KPI) and this concept are explored in greater depth within the literature review. Chapter 4 the finding from chapter 2&3.

Chapter 5 discuses aspects pertaining to the philosophy of methodology, and the paradigms and theoretical approaches considered for this study. Moreover, this chapter examines the methods of data collection and analysis employed to address the research questions; it also explains the rationale for choosing a mixed methods approach that collects both interview and survey questionnaire data. It explores sampling decisions, ethical considerations and an overview of how the methods are operationalised.

Chapter 5. Quantitative and Qualitative

First, Chapter 5 presents the results of the quantitative analysis performed on the data obtained from the questionnaires, which is expressed in statistics and illustrated by graphics. Second, the results of the qualitative data analysis are presented, in a narrative form that interprets the emergent themes drawn from verbatim interview transcripts. The latter include supporting extracts from the questionnaires to elucidate findings. Finally, as is the pattern of mixed methodology, the two sets of analyses are considered collectively in addressing the research questions.

Chapter 7. Develop ISM Framework for KSA Construction Industry

Chapter 7 focuses on the development of a framework for enhancing H&S in the public construction sector in KSA. In this section, the rationale for framework development is examined with reference to the literature review and through results obtained from the questionnaire survey and interviews. Crucially, the study takes account of the contributions to this framework that could be made by BIM technology. The framework was built by using by ISM to support the evaluation of H&S measures in the construction industry.

The discussion of results creates the possibility of a framework built by ISM for construction projects to enhance the current H&S practices by means of a sustainable technology-driven system developed through industry consensus.

Chapter 8. Discussion, Conclusions and Recommendations

The final chapter interprets the data by seeking aspects of both sets of data that support each other and those that fail to do so within the overarching context. Building from this secondary analysis, this chapter discusses the emergence of a possible framework for creating a basis for a consensual agreement regarding the ability of the Saudi construction industry to restructure its practices. A special focus is given to agreements that exist regarding the adoption of new technology, particularly BIM and its perceived contribution to H&S practices. The conclusions and recommendations offer insight to H&S practices and advance the current state of knowledge relating to the construction industry in KSA. This chapter presents and discusses the considerations of validity and integrity in the study. It also includes a discussion on reliability and offers details on how the study uses the concept of triangulation to demonstrate its findings. Moreover, the concept of “transferability” is explored as an alternative to generalisability. The limitations of the study are also noted and discussed critically, with suggestions for further study. Finally, the contribution of this study to existing knowledge and projections of practical applications is recorded.

1.9 Summary

This chapter has set out the background to the research, justified the rationale for the thesis and presented the research aim, objectives and questions. In addition, the research strategy has also been introduced. The next two chapters review the literature relevant to the general construction industry in KSA, construction specific-literature in H&S and the possible role of technology in advising, enhancing and permitting development H&S in construction in KSA.

Chapter 2. Literature Review of H&S Management Practices in KSA

2.1 Introduction

This chapter discusses the strong economic position of KSA, which drives the construction industry, focusing on the current status of that industry and the issues that affect its projects. In this chapter, previous research is reviewed as it pertains to H&S in construction management in general and H&S in KSA in particular. Both positive and negative aspects of H&S within the construction industry are presented. In addition, this chapter presents a discussion of the importance of communication and personal behaviour on construction work sites, as these relate directly to an employee's ability to remain safe and follow H&S regulations.

2.2 Search Strategy and Method

The main aim in carrying out the literature reviews is to gather information on the research topic. As will be mentioned in the references at the end of the dissertation, the principal sources are journal papers, seminar and conference articles, as well as archive material and governmental reports. The study begins with a detailed literature review. The nature and rationale of the Saudi Arabian construction industry is discussed, focusing firstly on its nature, scope and composition, and regulation and bureaucracy, as well as the activities involved in the workplace worldwide. The specific and unique challenges posed in KSA are examined. After investigating the scope, meaning and adoption of H&S precautions and regulations by countries in the developed and developing world, the literature review moves on to discuss possible documented challenges to H&S matters in construction management practices within KSA. It is hoped that the research questions develop through a rigorous examination of the literature and that these can also inform methodology chosen for the study.

2.2.1 Research databases

The main databases chosen were Science Direct, Google Scholar and university online library. This is because of their very wide range of searchable data in the construction field, as well as in other areas like H&S in construction and BIM, which could perhaps have some bearing on the subject of the review. The terms "health and safety" and "BIM" were also accessed. It was discovered that the journals referenced in these databases were available through the university. There was also considerable crossover between many online resources.

The bibliographic software chosen was Mendeley. One reason for this choice is that it allows direct export from the resources that were saved in the Mendeley account. Data can be exported as “abstract plus references”, so that the abstract can be read easily through accessing the references. Another advantage of using bibliographic software such as this is that it saves considerable time and permits far more extensive searches. Using Mendeley enables “hand-searching” through certain journals, for providing that these exist in electronic form, the journal itself can be searched electronically. Further, in contrast to the traditional method of preparing a list of likely titles, then accessing the abstracts of some of them and finally choosing a collection of abstracts, which process requires a full text version, the first two stages in a traditional search are bypassed. These electronic data were supported by inter-library loans and books borrowed and bought.

2.3 KSA and its Construction Industry

KSA is among the fastest-developing Arabian countries in the Middle East. It is the world’s largest oil exporter; therefore, its economy is growing day by day and the country is developing every industry, especially construction, in order to house, educate and provide for its population. Since 1970, KSA has established and implemented both medium- and long-term development plans to foster economic and population growth (Al-Farsy, 1990). Its medium-term plans are segmented into five-year-plans, the ninth of which has recently ended (Al-Farsy, 1990). The long-term aim is to reduce the nation’s reliance on its oil revenues and to build infrastructures that will diversify trade and provide options for economic, technological and educational enhancement. One major feature of current plans is the development of a high level of these programmes. As the population grows, due in part to immigration by foreign nationals who now form 30% of the population (Alhaadir & Panuwatwanich, 2011), the government is focusing on a large number of local and international construction companies that are engaged in the building of various new housing projects. Along with this remarkable economic growth, there is also the establishment of six economic and industrial cities across the country, new transport links and the building of schools and hospitals to support and extend the economic growth of a non-oil economy. The Saudi government is committed to major spending on the public construction sector, with investments of up to $91.9 billion from 2012 to 2014. In addition, $16.5 billion has been spent to have the transport network in Mecca renewed and improved (GCC Powers of Construction, 2013).

2.3.1 Construction projects and their organisation in KSA

There are both public and private construction projects currently under tender or in the design or build phase. Public building projects account for over 60% of all building in the country (Bubshait & Al-Musaid, 1992). This study focuses on the public sector of the construction industry only. The country employs a design-bid-build model (DBB). Major projects can be designed by large, often multinational, design and engineering companies, then the drawings, specifications and quantity surveys are sent out to a number of contractors, usually in computer aided design (CAD) format which is two-dimensional (2D) or three-dimensional (3D). Contractors, if their classification allows it, bid for the work. Contractors are classified by the Ministry of Public Works and Housing into differently numbered groups based mainly on their financial capability. A classification of ‘1’ represents those allowed to undertake the largest projects that could be offered – any building contracts in excess of USD74.66M – but a grade-5 company is limited to projects no higher in allocation than USD1.86M. (Al-Khalil & Al-Ghafly). The classification system also subdivides construction works into 12 categories, depending on the size of the project and its importance. The figures quoted above are for building construction but are different for all types of construction work. In KSA, regulations demand that the lowest bid is accepted and secures the contract (Shash & Abdul-Hadi, 1992). Then the project enters a construction phase, generally employing a variety of subcontractors. The bureaucratic issues surrounding the DBB process will, at this point, add another governmental ministry to the complexities involving building projects in KSA. The Ministry of Labour is the next route the contractors must navigate through.

The Ministry of Labour is the regulatory body that rules on who can work on construction projects. As discussed later in this chapter, for its labour-intensive civil constructions KSA tends to rely on migrants mostly from the South Asian continent (see Figure 2-1). These labourers are from rural communities suffering serious socio-economic deprivation. They are usually educated to a basic level only and many are barely literate.

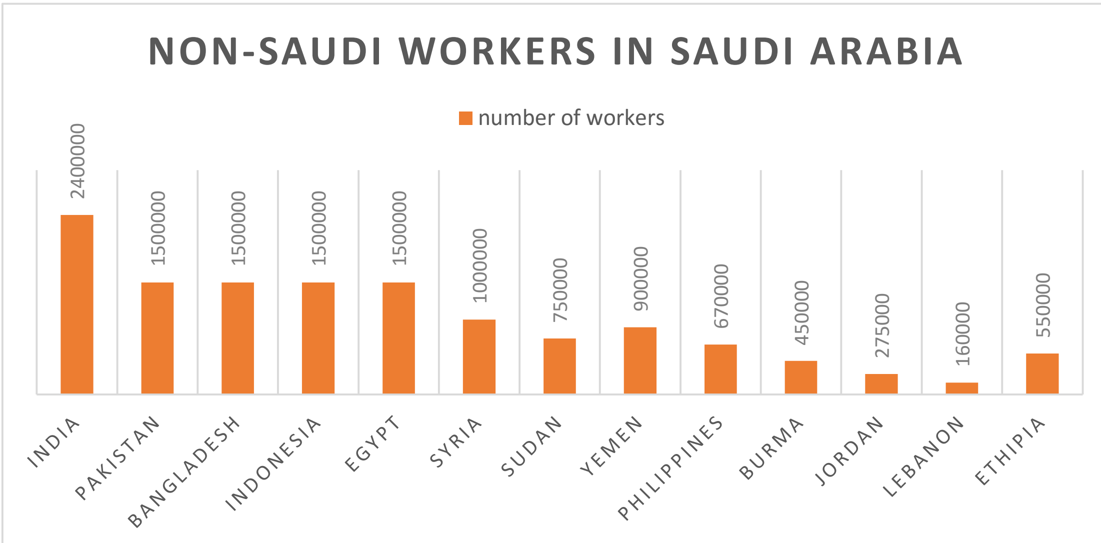

Figure 2-1: Non-Saudi workers in KSA
(Source: de Bel-Air, 2013)

They are employed on short-term contracts of three years or less and leave families behind in their own countries to take on this work that supports them. A recent review study by Salminen (2011) finds that immigrant workers, in a multi-country study, suffer disproportionately more injuries than native workers for the first five years of their tenure. After that, their accident rate drops and can be even more positive than expected and better in some cases than for native workers. One of the findings of that study was that immigrant workers appeared to be placed in the riskiest jobs (Lee & Wrench, 1980).

The Ministry of Labour has an additional responsibility that runs alongside the issue of visas to migrant workers. It is the issue of "Saudisation". This policy (named Nitaqat), to support unemployed Saudi nationals to find employment, is said to place certain additional, quota-based demands on the private sector both of construction and other industries (Hertog, 2014). KSA has a particular unemployment problem with young people. The under 25s now compose over 50% of the population (de Bel-Air, 2013). If a work culture is embraced by these young adults and suitable employment becomes available, that will place KSA in a demographically positive position in comparison with developed countries and China, which is experiencing problems of the opposite kind, namely, that the elderly and retired, those who contribute least to the national economy, are becoming the highest proportion of the population.

2.4 Construction Challenges in both Developed and Developing Countries

The construction industry, with this complexity of demands and the number of interwoven responsibilities created through various ministries and contractors, may face challenges. These include the problems created by the bureaucracy, outlined above, required to navigate through the construction process. There are two interdependent results of this confusion: delays and accidents. Delays often lead to unsafe and hurried decision-making and behaviours as constructors try to make up for lost time. The carelessness resulting from this haste, in turn, can lead to accidents, which then create further delay. Sidawi (2012) highlights that the Saudi construction industry is liable to face many shortcomings, including mistakes in construction work, changes to the project’s scope and specifications, cost overruns and delays. Commonly cited challenges include factors such as ineffective planning and control, poor site management, labour productivity, communication and coordination problems, and material procurement. In all industries that might be regarded as dangerous, statistics reveal that the majority of workplace deaths and accidents are in the construction industry, well above what might be expected from the percentage of construction workers in the workforce. Although many of these problems may be highlighted in KSA, they are counted among challenges to the viability of the construction industry worldwide. It is believed to be one of the most hazardous globally, despite a regulatory climate in many developed countries.

2.4.1 Delays and organisational challenges

A detailed analysis of causes of delays in Saudi public sector construction projects was undertaken by Alkharashi and Skitmore (2009). They drew up the top five reasons for owner related causes of delays, which included those in revising and approving design documents by the owner and the owner’s poor communication with the construction parties and government authorities. In addition, there may be slow decision-making and delays in the progress of payments by the owner, and delays in finishing and delivering the completed site.

In addition, as revealed in the questionnaires employed by many of the researchers in the Saudi construction industry field, there appears to be a broad consensus of the importance of active communication and management to maintain construction processes. Nevertheless, it has also been highlighted in the literature (Salleh et al., 2012). That issues resulting from the disjointed nature of construction processes, poor data exchange and interoperability, as well as overdependence on documents and the written word to guide the workforce. Changes to the project's scope and specifications during the construction itself are common but counter-productive. Also, cost overruns were emergent factors in the results obtained. All factors constitute challenges to working activities that may lead to delays in project completion.

Worldwide, the construction industry faces similar challenges, and governments are the biggest clients of the construction industry, as they sponsor huge infrastructure projects, particularly in developing countries. As identified by Jaselskis et al. *(*1996), there are several characteristics of the construction industry in developing countries, including long procedural requirements, evident in the Saudi Arabian context, interruptions to the work and a shortage of materials. In addition, Thomas (2002) underlines specific issues encountered by construction industries in emerging economies, which include failures to use technology, ineffective methods, complex cultural settings and the absence of regulatory systems. Further, as highlighted in several studies that pinpointed failed construction projects and delays, are performance related issues and failings (e.g. Government Construction Strategy, 2011; Ugwa & Haupt, 2007; Navon, 2005; Karim & Marosszeky, 1999).

One common cause of project delay identified by all project stakeholders is "change orders". Also, Alsuliman et al. (2012) observe that variation of order management is not fully understood nor well applied in the Saudi construction industry. Other factors contributing to project delays, they claim, include delays in the progress of payments by the owner; and on the part of the contractor, ineffective planning and scheduling of the project, poor site management and supervision, shortage of labourers and difficulties in financing the project. Also, all three parties agree that the following factors are the least important cause of delays: "changes in government regulations and laws, traffic control and restrictions at job site, effect of social and cultural factors and accidents during construction" (Assaf & Al-Hejji, 2006, P365).

Al-Khahil and Al-Ghafly (1999) conducted a survey in the Saudi Arabian construction industry with questionnaires about delays in building projects sent to owners, engineers and contractors. The frequency of delays ranged from 16% in grade-2 companies surveyed to 56% in classification grade 4. The authors conclude that factors causing delay were principally cash flow problems and difficulties in obtaining work permits, but an important part of the discussion of results was: "… the government practice of assigning contracts to the lowest bidder without regards to qualification. The lowest bidder may not be able to work with the increased project complexity, or the increased demand on management expertise for large public utility projects" (Al-Khahil and Al-Ghafly 1999, P 102).

A similar conclusion on a major element in the KSA's record of construction delays is reflected in the study undertaken by Albogamy et al. (2012), which concludes that "low performance of the lowest bidder contractor in the KSA government tendering system" was the most important factor in construction delays. Kartam et al. (1998) point to similar problems in Kuwait that concentrated, above all, on the safety of construction sites. Administration and organisation were poor, construction companies were often too small and, being subject to competitive tendering, had limited profit margins and, therefore, by-passed some responsibilities that might impact on cost effectiveness. This report reflects many of the concerns that occupy researchers in KSA.

This conclusion is important in developing aspects of the research questions in the current study, as it shows up a major problem in the DBB model that is widely used in the construction industry worldwide. Interestingly, too, this study cited "delay in preparation of shop drawings" and "design changes by the owner" as other delaying factors (Albogamy et al., 2012). The issues of design changes and "preparation of shop drawings" are discussed later in this chapter, which now moves to examining the challenges provided by the environment of construction sites.

2.4.2 Environment, hazards and injuries

The environment includes the workplace, where people perform their duties; and a construction site is considered a very dangerous workplace, where the ratio of hazards is always at its peak. Different hazards, including physical and psychological hazards, can be experienced at construction sites. Physical hazards are almost unavoidable when it comes to working in fields such as construction and mining. However, with the passing of time, people have developed different methods to prevent as well as manage these hazards. A major reason for physical hazards is the employment of younger workers and the unskilled because often they cannot handle critical situations or lift heavy materials safely. The major causes of accidents are related to the unique nature of the industry, human behaviour, difficult work-site conditions and poor safety management (Jannadi et al., 2002).

Even in developed countries, deaths and accidents occur in the construction industry. Davies and Tomasin (1996) state that there are many reasons why the rate of accidents in the construction industry is higher than expected, compared to accidents and injuries in other manufacturing industries. According to Zhang et al. (2013), the last two decades have seen more than 26,000 employees in the USA lose their lives in construction projects, which is equivalent to five people per day. There was an average of 1,089 deaths annually in the American construction industry between 1992 and 2012. During the same time period, the construction industry suffered an average of approximately 19% of all workplace related deaths, as shown in Figure 2-2 (Bureau of Labor Statistics, n.d.). These statistics make construction one of the most dangerous professions in the USA and it is consistently in the top five most dangerous professions in terms of deaths per capita. Moreover, 120 people died on construction sites in the UK, one of the safest and best-regulated construction industries in the world, while about 3,000 site workers experienced severe accidents on construction sites (Barnard, 1995).

It is suggested in some research studies that there are several different factors for high injury rates within the Saudi construction sector, including the fact that the majority of these H&S related incidents were brought about by a considerable lack of governmental H&S management. Another factor that contributes to the high injury rates is that most of the work (95%) is carried out by migrants and expatriates, who are likely under-experienced and under-trained (Alasamri et al., 2012; Jannadi & Assaf, 1998; Al Haadir & Panuwatwanich, 2011).

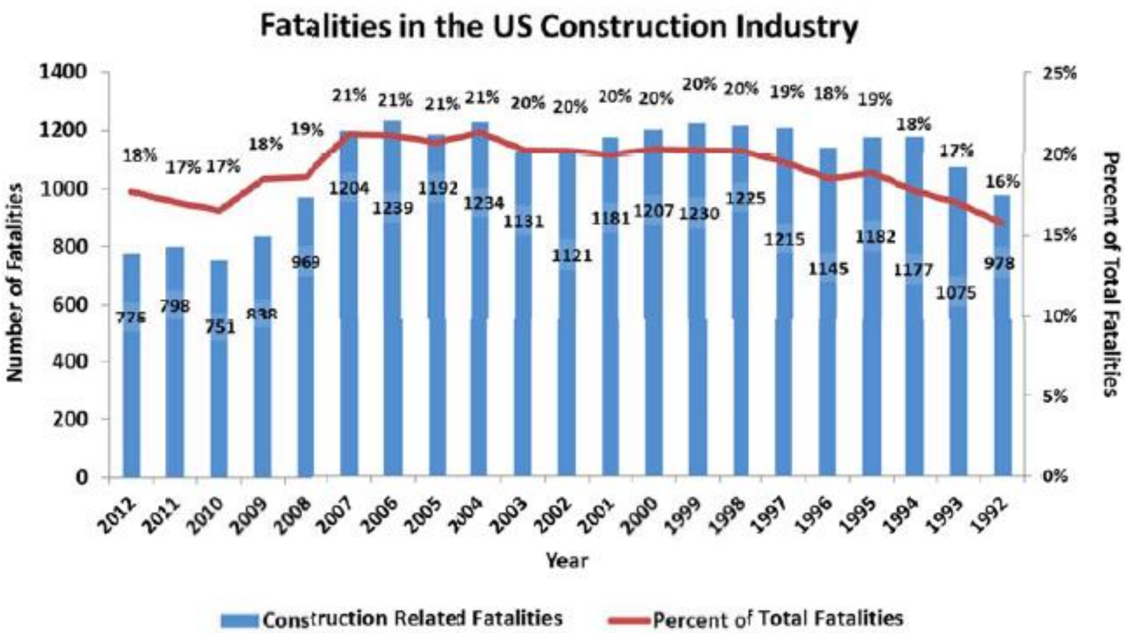

Figure 2-2:Accident data for the US construction industry

(Source: Bureau of Labor Statistics, n.d.)

In developing countries such as Saudi Arabia, as recorded by the General Organization for Social Insurance (2010, 2011), worker injuries in the construction sector is the highest amongst the compared sectors, topping at almost 60% (GOSI,2010-2011)(see Figure 2-3).

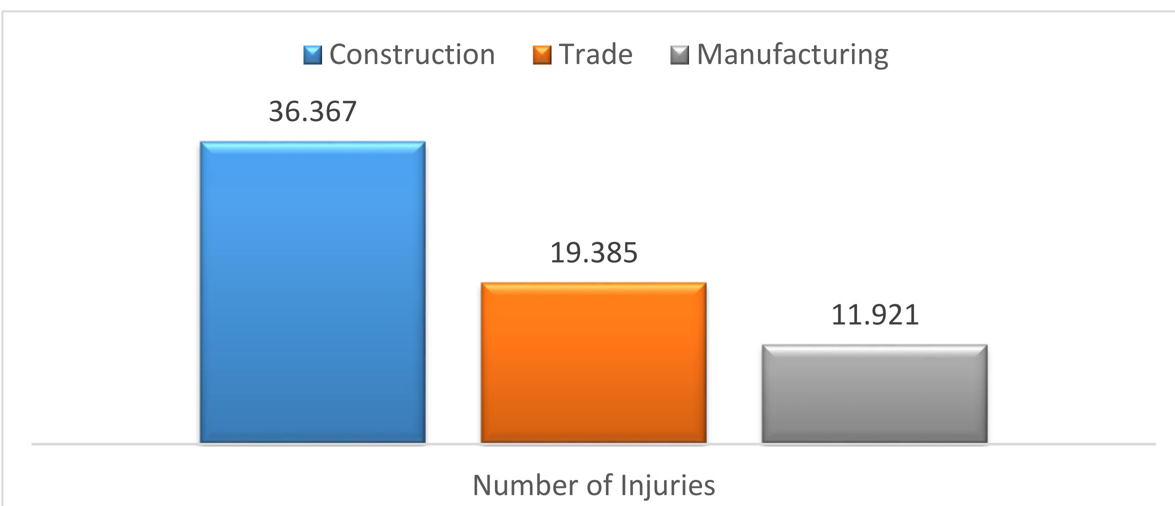

Figure 2-3: Worker injuries in construction, trade and manufacturing in KSA

(Source: GOSI, 2011)

Several studies have been conducted over decades to identify further the different general causes of accidents on construction sites. While some studies share similar views on certain causes of accidents, some views differ completely. According to Wolf and Brick (1996), accidents occur due to poor project design, poor choice of materials, unsuitable equipment, poorly organised workplace, poor coordination of workers, simultaneous activities, poor training, non-observance of regulations and non-compliance with safety regulations. Similarly, Sawacha et al. (1999) suggest that the poor safety performance of the construction industry is due to a lack of knowledge, poor training, lack of supervision, lack of means to carry out the task safely, errors of judgment, carelessness, lack of concern and recklessness. They also cite the nature of the construction industry, the lack of a controlled working environment, the complexity and diversity of the organisations, unsafe behaviour, poor safety culture and poor management action. Nevertheless, the study by Bashir (2013) views the low level of education and lack of adequate safety training of workers as the main contributory factors. Ndekugri and Corbett (2004) further identify the fragmented nature of the industry as one of the causes of poor safety performance.

Machines commonly used in various industries, such as manufacturing, agriculture, mining and, more specifically, construction, can be very harmful to workers if not operated properly. Some machines consist of moving parts, hot surfaces and sharp edges that are a necessary part of the machine but dangerous to workers, thousands of whom have lost limbs (Fang et al., 2004). In 2008, the USA Bureau of Labor Statistics reported 64,170 injuries caused by machines whereby the operative remained absent from work for many days. Over 25% of cases required more than a month's recuperation at home or hospital. In the same year, more than 600 work related deaths were reported that were directly or indirectly caused by machines (USA Bureau of Labor Statistics,2008). H&S is often not taken into consideration when deciding what equipment and machinery is to be used. High-rise construction projects require workers to climb to the particular floor that is the current location of operations. It is the duty of the site manager to choose between a self-climbing machine and a framework climbing system. Each has properties and benefits, but if any fails to perform as expected and predicted, the lives of workers could be endangered. It is important to consider all aspects because workers are the main power of any organisation and must feel safe at work, if the organisation is to be successful (Lin & Mills, 2001).

Globally, hazards include a high number of falls from a height that cause injuries and sometimes deaths. In Kuwait, construction is the most hazardous industry, with accidents accounting for 48%, 38% and 34% of all disabling injuries and 62%, 38% and 42% of all deaths in 1994, 1995 and 1996, respectively, with falling from a height the main injury (Kartam & Bouz, 1998). A study of the admission rates for falls in a hospital in Benin, Nigeria, included the statement that “falls at construction sites and off the top of a moving lorry recorded in this study were not unconnected with alcohol consumption”. The consumption of alcohol on construction sites is allowed in Benin. In a study in that country, falls on construction sites from the top of a building accounted for 9.5% of hospital admissions in a 12-month period in 2007-2008 (Osifo et al., 2010). Falls are the cause of many serious injuries and deaths. More than half of falls in construction are related to environmental factors involving, to some extent, the working surface or facility layout conditions. Inadequate or inappropriate use of fall protection personal protective equipment (PPE) and removed or inoperative safety equipment contributed to more than 30% of falls (Huang & Hinze, 2003).

In addition to these, other factors that are associated with accident causation include poor supervision, poor communication of information, poor training and poor selection of contractors (Anumba et al., 2004; Hughes & Ferrett, 2008). Kletz (2001) suggests that important causal agents were a lack of training, motivation, physical or mental ability, and slips and lapses of concentration. Human actions and functional limitations is the summation of McClay’s (1989) study of the cause of accidents, while Abdelhamid and Everett (2000) hold management deficiency responsible. Poor training and workers’ attitudes are cited by Molenaar et al. (2002), while Toole (2002) places the blame for accidents on problems that could be averted with a properly managed code of practice and H&S training, He cites a lack of proper training, inadequate safety equipment and poor enforcement of safety requirements as major causes of accidents. Management failures are held strongly responsible for accidents and hazards (Maloney et al., 2004; Fang et al., 2004). Hughes and Ferrett (2004) concentrate on communication problems, with poorly communicated procedures and poor verbal communications highlighted; and in the same vein, Donaghy (2009) notes missing or incorrect signs and attributes blame for this to a lack of knowledge.

In a survey of the safety issues on construction sites in KSA, Jannadi and Assaf (1998) examine practices at 14 randomly selected sites of projects undertaken by the Saudi Arabian Oil Company (Saudi Aramco). Results show that larger construction sites pay more attention than small sites to safety issues. Of the small sites surveyed, none had any means of fire protection, while on large sites this was also the most neglected area. Smaller sites also showed problems with health and welfare, and with safety administration. Al-Haadir and Panuwatwanich (2011) quote Berger's (2008) results that 25% of construction sites surveyed provided no PPE. In a similar study to that conducted by Janaddi and Assaf (1998), Kumar and Kumar (2012) report on construction sites in Sri Lanka:

> Usage of personal protective equipment is very minimal. Helmets are not familiar in most of the sites. Awareness among the workers regarding the usage of PPE is lacking. The contractor / employer is not providing the PPE to the labourers at their site. In some sites, even though workers are provided with PPE, workers are not using it properly. For example, workers are using their helmets for storing and carrying oil (p. 30).

A similar study (Choudhry et al., 2007) examines the safety issues of Hong Kong's construction industry, examining, through interviews, the question of why operatives engage in activities on building sites that are hazardous to their health. One important conclusion reached is that there are deep psychological reasons for these practices, besides obvious practical problems like lack of safety training and those that involve self-esteem issues, "acting out", fears about job security and performance pressure. Research indicates that in several developing countries, serious challenges can be posed to the organisation of construction processes that share characteristics with the construction industry in KSA. Similar studies have been conducted in, for instance, China (Tam et al., 2004), Thailand (Aksorn & Hadikusumo, 2008), Singapore (Ling, Liu, & Woo, 2009), India (Vinodkumar & Bhasi, 2010), Taiwan (Cheng et al., 2013), and Nigeria (Osifo et al., 2010) . While some of these certainly involve elements of administration and bureaucracy, many involve H&S issues.

This review now touches on the process and performance of H&S in the construction sector, including an overview of H&S management and recognition of other current management practices that may have an impact on and led to the establishment of H&S management in the construction industry. This section concludes by emphasising the issues and gaps in the current body of research, which has been utilised to explain and shape the course of the study.

2.4.3 Regulation of H&S

H&S in construction has been described by a number of researchers as the carrying out of work duties and activities following H&S guidelines which are aimed to minimise or remove hazards in the workplace. For example, Anton (1989) states that the adoption of H&S practices is decreasing work related injuries in the workplace by regulating working conditions. In addition, safety culture can impinge on professional behaviour in terms of increasing or decreasing the hazards faced by businesses. Decision-makers in the industry have favoured H&S programmes, since they protect workers and can be cost effective in terms of money and time. In the last ten years, a key aim of construction industry management has been to minimise the number of people injured, loss of life and sickness as a result of risks in that sector (Choudhry et al., 2007). As such, H&S is now one of the most important subjects for scholars, as its understandings can be responsible for avoiding serious threats to health in the workplace.

In developed countries, there is typically a governmental organisation that oversees H&S in the workplace. This organisation creates the safety standards for all industries, not only the construction industry. The latter, unsurprisingly, has more safety standards than any other industry. This organisation, no matter in which country it is located, has responsibility for ensuring that these safety regulations are met. This is effected through on-site inspections that are unannounced and through a system of leveraging fines and possible site shut-down if the regulations are being violated in an extremely dangerous manner (Kohler & Hassler, 2002). However, the construction industry appears to be specifically hazardous in relation to the percentage of the workforce employed in the industry. This is why many developed nations have set up a wide-ranging regulatory body to oversee the industry's H&S practices.

In the USA, the Occupational Safety and Health Administration (OSHA) oversees workplace safety in the construction field. This organisation was established in 1970 and provides training and training documentation, as well as instituting complete policies and regulations that all construction companies and their employees are expected to follow. OSHA also conducts unannounced inspections of construction sites to ensure all regulations are being followed. The majority of these regulations are focused on safety. Companies not following these regulations can receive fines which are sometimes quite large. They even run the risk of having their entire construction site shut down as presenting an unsafe environment.

The UK established construction safety and health regulations under the Health and Safety at Work Act, 1974. One of the most important aspects of this act is that when the regulations are not followed and there is a serious accident, it is considered a criminal offence. There are different levels, but the fines imposed can be unlimited. All this is enforced by HSE, which was set up in 1974 following the above act. A construction division was established in April 2002. While a company itself can be considered at fault and face the consequences, an individual, a director, a manager or another person found responsible can be held accountable for their actions (HSE, 2013). In construction, HSE is also responsible for training and site inspections. The UK H&S regulations have been modified a little in recent years to allow for an additional level of input from contractors. The regulations are currently more proactive and cooperative than they have been for many years.

H&S regulation, requirements and recommendations in these and other developed nations usually contain most of the following requirements within the remit of a H&S framework:

- H&S guidelines issued through all industries
- Training frameworks established, inspected and examined with designated trade requirements
- Practice codes established in agreement with professionals and workers in the industry
- An awareness of hazard situations understood and communicated throughout the workforce
- Regular site inspections carried out though the industry
- Safety equipment made mandatory

- Information and guidance provided by a central trade body
- KPI agreed on, established and integrated into performance assessment
- Regulation, where it applies, can be backed by legislative powers if necessary
- Medical care and first aid supplied on site
- Management-worker communication on all safety issues, including safety notices and signage, safety warnings, safety meetings, safety equipment supplied, lines of communication established if emergencies should arise
- Awareness by labourers of the layout and accessibility of the site
- Site kept clear of all hazards
- Training on the operation and maintenance of all machinery by those who might operate it

H&S situation in developing countries

One of the major reasons behind the high number of incidents and accidents recorded, especially in the developing world, is a failure to apply stringent regulation of H&S standards. There is, it is claimed, an absence of H&S management in construction in some developing countries (Chaudhry et al*.,* 2007). As referred to in previous sections, KSA has a confused and confusing range of ministerial responsibilities, with little evidence that approved H&S frameworks and recommendations are enforced on a regular and consistent basis; and there may be a number of irregularities on H&S grounds, especially in the practice of applying any national guidelines to H&S regulation on construction sites, particularly in those managed by smaller construction firms (Jannadi & Assaf, 1998).

In China, H&S is considered a major concern because of the increase in construction projects. Numerous workers have been subject to injuries and health problems. The National Bureau of Statistics of China states that of 35 million workers in different industries, about 3,000 workers are killed in work related accidents each year in the construction field only. In this regard, China has taken various steps to ensure the safety of workers in the workplace (Kenrick, 2012). It uses a safety benchmarking approach to evaluate the condition of physical safety at the construction sites. Now, China uses a 'standard of construction safety inspection' to evaluate the safety conditions on construction sites. If a company is providing H&S protection, the authors claim, no matter if it is paying less, workers will remain in that that company. Internationally, every company is currently considering appointing H&S professionals in order to maintain the H&S of valued workers.

The construction industry is specifically different all over the world and standards are not uniform. It should be taken into account that the construction industry plays a vital role in the developing economy of a country. It provides the infrastructure – transport, homes and business premises – required for other sectors of the economy to flourish. According to Coble and Haupt (1999), the construction industry reflects the level of economic development within the country. That sector, like any other, has its own challenges and problems. However, in the case of the developing economies, problems are more serious due to the vulnerability of the economic and social environment (Ofori, 2000). The construction industry is also the major source of employment, as it can employ those with a wide variety of skills, from labour, to semi-skilled, to skilled and specialised workers. However, research and development in this particular area is very poor and the training provided to the employees for safety and client satisfaction is increasing the costs of the industry while reducing the profit margin of the contractor.

As identified by Jaselskis, and Ashley (1991), there are several negative characteristics of the construction industry in developing countries, including long procedural requirements, interruptions and shortage of materials, as has been noted in other sections of this review. In addition, Thomas (2002) underlines specific issues encountered specifically by construction industries in emerging economies, which include the failure to use technology, ineffective methods, conflicting cultural settings and the absence of regulatory systems. Also highlighted in several previous studies when pinpointing failed construction projects are performance related issues and failings (Government Construction Strategy, 2011; Ugwa & Haupt, 2007; Navon, 2005; Karim & Marosszeky, 1999). In the case of KSA, there are several construction developments that fail to deliver in terms of performance. Moreover, current performance assessment systems are either absent or ineffectual.

The construction industry in developing economies cannot meet the standards of developed economies; it often fails to meet the needs of the modern competitive business model and does not provide value to the client (Datta, 2000). Furthermore, the sector has a high rate of accidents, due to the absence of H&S laws. According to ILO (1987), the main reasons for the poor safety record in the construction industry of developing countries is the high number of self-employed workers, the very short life span of construction sites, very high labour turnover and a very high number of the seasonal and migrant workers.

According to Kim et al. (2013), in construction sites in most developing countries there are no training programmes for staff and workers; therefore, no orientation for new staff or workers is conducted, hazards are not pointed out and no safety meetings are held. Employees are left to learn from their own experience and the mistakes they make. This is very different from the situation in developed economies. The two main differences between the developing and the developed economies, as referenced in the previous section, are the developed nations' strict laws, regulations and hazard awareness. Furthermore, in those countries, proper training and H&S equipment are provided to employees. There is a nominated H&S officer who provides training sessions to employees on how to be safe on site. However, in the case of developing countries, these laws are often ignored, with H&S practices used that are out of date, ineffective and based on conditions that prevailed while the country was still being colonised. Additionally, the regulatory authority is usually very weak in implementing rules effectively, and work hazards are either not perceived at all or to be less dangerous than they actually are (Larcher & Sohail, 1999; Hinze et al., 1999).

With its increasing economic progress, the Saudi construction industry has expanded enormously. It attracts millions of employees, not only from KSA but also from all corners of the globe. As highlighted by Haadir et al. (2011), despite its economic progress and financial growth, H&S in construction within KSA remains extremely poor, as referenced earlier. Table 2-1 presents the result of a comparative study indicating that Saudi injury rates are the highest amongst comparable countries.

As evidenced by Alasamri et al. (2012), as regards safety the Saudi construction sector has recorded the highest number of injuries and deaths in a comparative study of eight developed and Arab countries. Many construction sites in KSA have been built without any form of protective parameters, which provide no security for pedestrians. For instance, Berger (2008) reports that, in 2006, 25 people lost their lives while a building was being demolished in the holy city of Makkah. Applying a countrywide policy regarding construction H&S would certainly reduce accidents and injuries but, in addition, would bring additional revenue into the country in the forms of fines. However, like in the UK, such a policy would require the country to be consistent in enforcing the regulations. Multiple inspectors, their enforcement of laws and cooperation among them are possibly needed.

Table 2-1:Comparative study from 2008

Country	Labour (Thousands)	No. injuries	No deaths	Rates of major injuries/ 100,000 employees/year	Rate of fatal injuries/100,000 Employees/Yr.	Date issued
United Kingdom	2404	Major 3286 / Minor 6789	53	254.1 / 524.9	3.4	2008
Australia	926	Major 1621 / Minor 13118	55	175 / 1416	5.9	2008
United Arab Emirates	1349	Serious	20*	233.03*	6.7*	2008
United States Of America.	13735	Major 164900 / Minor 316800 / Job Transfer 207900	975	1200 / 1500 / 23000	9.7	2008
Kuwait	127	Serious 1257	13	1013	10.4	2008
*Jordan	374	Serious 2306	-	615.9	-	2008
Bahrain	133	Serious 475	-	357.1	-	2008
Saudi Arabia	1248	Serious 38929	-	3117	28.19	2008
Max Rate of Non-Fatal injuries (major)	3111 per 100,000 (Saudi Arabia)					
Max . Rate of Fatal injuries	28.19 per 100,000(Saudi Arabia)					

(Source: Alasamri et al., 2012)

2.5 Safety Culture in KSA Construction Industry

As this review has focused on the environment as the source of safety hazards, attention is now turned to other factors. Cooper (2009) adapts a three-way model from Bandura as he attempts to explain the meaning of safety culture (see Figure 2-4). Bandura (1986) was the first to suggest that when looking at a social process, one should understand that no element in it operates just as a single force. He creates the notion of the triangular relationship between person, behaviour and environment in which each element has a bidirectional effect on the other two. He calls this reciprocal determinism (Cooper, 2009). This is a useful model to look at when trying to understand what exactly a safety culture is. Bandura (1986) sees these three elements as crucial to a group understanding of what contributes to any process and Cooper adapts this basic model to explain the difficult idea of “safety culture”.

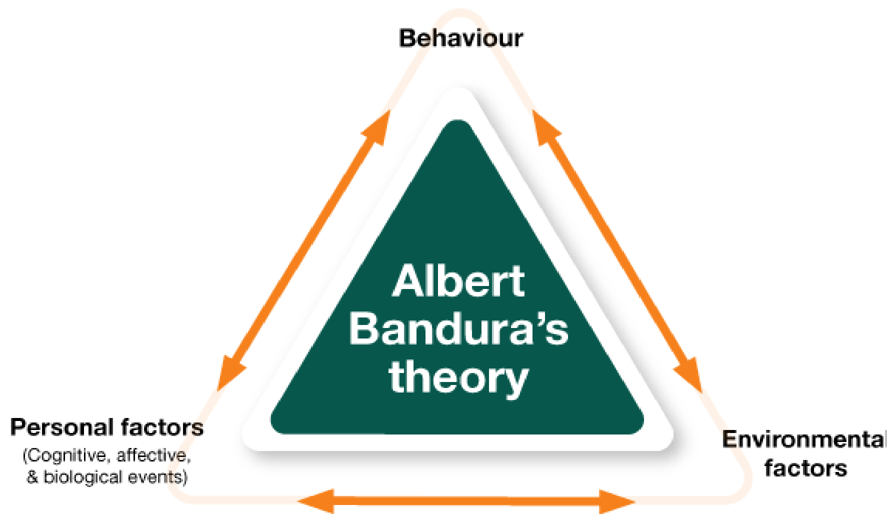

Figure 2-4:Bandura’s theory (1986)

The environment in which construction takes place in KSA, as has been described, is a major factor in considering hazard and risk. Large earth-moving machinery operates on construction sites; workers may be operating nail guns and climbing to heights but may not be fully protected in this work. Sometimes, as stated, protective clothing is not issued or, it has been claimed, is issued but then sold by the worker; also, long hours must be worked, sometimes in blistering heat, sometimes without breaks (Berger, 2008).

Here one can see how the environment can impact upon behaviour and how the behaviours caused by this have an impact on the people hired to do the job. It is also put forth that this impacts the people who are trying to complete a project in a given time. Any delay caused by giving break times or insisting that correct safety procedures are followed, will cause financial penalties to the contractor or owner; if his business is small, he may then be unable to pay wages to the workers. In a research study by Al-Khalil and Al-Ghafly (1999), results of a questionnaire on building delays indicate that contractors blame owners for delays and that owners blame contractors. Delays in the KSA construction sites they studied appear extreme in most cases, with an average time overrun of 70% on public projects. Overruns inevitably lead to financial loss and this means that people suffer threats to their security and wellbeing, which consequently may be reflected in the way they behave at work.

2.5.1 *Kafala* and working practices

This is the dynamic that underlies working practices in KSA. But there is another major factor, often ignored in research, which has a very significant effect on the construction industry and those who work as labourers, unskilled or semi-skilled workers. It is that in KSA and in some other Gulf countries, expatriates from Western countries may be part of management-level contracting and design teams, but there is the *kafala* in operation, a visa system that brings in labourers from other countries. This system may undermine efforts to design and implement safety procedures, as construction labour is largely made up of migrants. Those non-nationals are said officially to number 9.5 million, but there are estimates that a further 5 million may have settled and now work in KSA, some of whom have entered the country for Hajj and others who have crossed the border from Yemen, in particular (de Bel-Air, 2013). Migrant labour accounts for 30% of the population and 50% of the workforce (FIDH, 2003). Therefore, it is important to note that not all threats to a safety culture arise only from environmental forces. It is the focus of this section of the review to place the threats posed by the *kafala* system to the individual labourer in KSA as central to the considerations, barriers and challenges around H&S management in the unique environment of KSA.

The *kafala* system basically limits the entry of any worker to KSA unless they have been individually sponsored. The sponsor is made responsible for recruiting this person from an agency for a definite job, for a minimum of two years; for that time, the worker must do the job for which s/he is sponsored and is not free to work elsewhere or travel out of the country. The sponsor pays the recruitment fee (Khan & Harroff-Tavel, 2011). However, those wishing to work may be asked to pay high sums of money to the recruitment agency in their home country and some may not be paid for the work they do at the end of the two years (Human Rights Watch, 2013).

Although this system can be seen as helping KSA to achieve its goals in building the infrastructure of the nation, and although many foreign nationals welcome the opportunity to work and earn wages in a more lucrative workplace than at home, there are said to be many abuses of the system (de Bel-Air, 2013). Amnesty International, in a report in 2013, also points out that these migrant workers could be housed in sleeping places that are too small and lack basic amenities; then having slept in these cramped dormitories all night, workers are still expected to work for excessive hours in temperatures of 45°C (Amnesty International UK, 2013).

Those entering the country come principally from the Indian subcontinent – India, Pakistan and Bangladesh (de Bel-Air, 2013). There are also many from Indonesia and the Philippines and KSA's near neighbours, Egypt, Syria, Jordan, Lebanon, Yemen, Sudan, Somalia and Ethiopia (see p. 18). One of the important factors that unite this group of workers is that they have arrived from rural areas, rather than from cities. They may know nothing about high-rise construction in urban settings and may never have seen it. Some may be leaving countries that are engaged in civil war. A percentage of these people are women, entering the country to work as domestic servants. But many are men employed in the construction industry and some are subject to threats if they report safety breaches:

> My arm was cut off while I was working at the controls of a heavy machine … An Indian worker drove me to the hospital. I heard the Saudi boss tell the Indian over the phone to tell the police I was in a car accident, which he did (Human Rights Watch, 2015, p. 4).

This large workforce, representing one-third of the population of the country (de Bel-Air, 2013), was originally seen as essential to KSA growth. However, there are now some doubts about the advisability of this number of migrant workers when there are many unemployed youths in KSA. As aforementioned, there has been a drive since 2011, *Nitaqat*, to limit foreign workers through quota targets, so that the country's young men can find work. The underlying reason for this is that the Saudi population has been increasing, yet since 2004 appears to have reached a plateau and is now decreasing, so there are now many 15-19 years-olds. The population rate of youth, boys and girls has now reached over 20% (de Bel-Air, 2015, p. 4). Therefore, there is a need for jobs to be made available to young people.

In 2015, many migrant workers who had outstayed their visa and had not left the country during a two-year amnesty were rounded up and expelled. A Human Rights Watch paper (2015) detailed the work of researchers in interviewing 60 of these workers, many of them from Yemen and Ethiopia, from November 2013 to February 2014. During this period, KSA was said to have deported almost 400,000 people.

Following this, in 2015, Saudi labour laws were amended, creating new workers' rights. These encouraged the employment of Saudi nationals and training for them. The rights of most male migrant workers were increased, too, as were enforcement fines, which is an important step forward in creating a safety culture.

2.5.2 Concept of safety

The establishment or the definition of a safety culture assumes or suggests that those people within a safety-seeking workplace have similar cultural beliefs, attitudes, experiences and goals. This applies to any workforce that is segregated into their own bands as regards their level of satisfaction, goals and sharing. Those at the same socio-demographic level may share similar understandings and goals. They may be willing to work up to the next level in physiological, social and psychological terms. The migrant workers in KSA do not conform to this pattern. As referenced by Mearns and Yule (2009), human needs and aspirations and the way human needs are shaped have been demonstrated by Maslow in his goal-driven, progressive 'hierarchy of needs' (1943).

The first need for humans, Maslow said, was to have enough to eat and drink, to sleep and feel warm or cooler when that was necessary, and have all basic needs met as far as the body is concerned. These, in total, are named in the diagram as physiological and are the first step in the pyramid of needs that should be satisfied (see Figure 2-5). Unless those needs are met, one cannot progress to considering higher things. It is very rarely taken into account that there is a need to make sure that these physiological needs are met first before a workforce safety culture can be created. No H&S understanding, design or research to date has dealt with that simple issue. H&S research has generally taken a developed world perspective that may not be appropriate in some settings, environments or workplaces. Therefore, working practices in KSA and states that employ workers on temporary visas, sometimes housed in poor conditions, often working long hours and living apart from the support of family and spouse, make these cases particularly unique, even when studying H&S in the construction industry in the developing world.

Figure 2-5: Progressive hierarchy of needs
(Source:Maslow1943)

Barriers to social support and solidarity

One of the key ingredients in formulating a code of safety in a working environment is building on the fact that trust between members of the workforce makes a strong foundation for agreements about mutual protection. Most workers experience a strong sense of solidarity, a sense that however difficult the tasks and demands may be, a belief that everyone can offer support to others is paramount. Safety codes often operate through workers looking out for each other and prompting others to be safety conscious (Friend & Kohn, 2014). However, in a workforce as diverse as that found in KSA construction sites, there may be barriers to this kind of mutual support developing.

One reason for mistrust may be the fact that construction sites, by their nature, are temporary and that the workforce has high mobility, as it moves from one place to another when the project is complete. Some may work for subcontractors employed for only a short time in a phase of the programme; hence, there is little time for labourers to get to know each other in these conditions. The multicultural nature of the migrant workforce is also a barrier to the easy friendships that often develop in a fixed workplace in the developed world where there may be some diversity, but perhaps not major cultural differences. In most countries, there would be some migrant labour, but almost the entire labouring workforce in KSA is composed of members of very many culturally diverse nations.

It may be interesting and useful to define various cultures in this way, which does give us some means of classifying certain cultural qualities, although its validity has been questioned. The dimensions were developed from on-going surveys of international IBM employees for six years. The theory is widely accepted within organisational behaviour research; but in this current study, it is only used to point out that there are some claims that the values, beliefs and attitudes that appear to define a society or a nation can be thought of as national cultural attitudes. In this respect, labourers from different societies may have different cultural beliefs. Some of these may be barriers to a close and mutually trusting attitude that is thought to characterise many workplace behaviours that can lead to collective responsibility for safety procedures, especially if contact with representatives of other cultures is superficial and temporary.

Cultural differences may play an additional part in attitudes to safety. Some people from rural societies, with little education and where societal advancement is rare, may adopt the belief that no one has control over their personal future and that their own circumstances may be determined not by themselves but by chance. This attitude, called “fatalistic” by psychologists and also termed an “external locus of control”, may involve certain religious beliefs. In conditions like this, a safety culture may be poorly received. The predominant cultural view may be that what occurs may be predetermined. Littlewood and Dein (2013), in writing about this issue, refer to the use of *“inshallah”* that was constantly present in the interviews they held. Meaning “if Allah is willing”, they say it is often a feature of the culture they were researching. It could be said that a strong belief in that view may work against safety culture. If members of the workforce believe that there is a predetermined route to survival, then a safety culture may be threatened, as there could be a cultural assumption that there is no means to escape what is not and has never been, under their own personal control, life and death. This section of the review has surveyed the various barriers to acceptance of a safety culture but it now explores the most significant of barriers – that of communication. In the Phua et al. (2010) survey, 34% of managers said that communication problems decreased safety standards, which indicates that language barriers are an important factor when considering H&S.

Language barriers

Cultural barriers can certainly cause failures of communication, especially regarding the usual ways that people of different nations can demonstrate different behaviours. Bovee and Thill (2005) appear to understand them: "Today's increasingly diverse workforce encompasses a wide range of communication challenges, including skills, traditions, backgrounds, experiences, outlooks and attitudes toward work, all of which can affect communication in the workplace" (p. 64). But the most obvious way in which communication can create problems for H&S practices in a multinational workplace is the language barrier, especially if the language of the host country is complex and difficult for non-nationals to understand. In KSA, because of migrant workers, there can be 16 different languages spoken on construction sites, not merely English and Hindi. The latter does not feature in the world's 12 top languages, in general, but English is the world's leading language (Coulmas, 2013).

A multilingual workforce presents problems in the hazardous setting of a construction site. As early as 2004, Chan claimed that language, cultural barriers and misunderstandings could get in the way of effective communication and create safety complications in the workplace. Ways have to be found to warn workers of dangerous situations, to lead them towards the next working location and remind them to wear protective clothing. Signage in 16 languages may be impossible. One way of dealing with this challenge is to adopt a "language of work", and in many workplaces this is usually English, as it is the most widely used throughout the world and is the language of the media. Signage could be in this language and the two other most-used languages in the team. In some workforces in the construction industry, inductions are given through video recordings in all languages (Phua, 2010). Another alternative suggested in the literature is to use visual signage on construction sites (Tutt et al., 2011), while "replacing written notices with clearly understood symbols or diagrams" is the instruction given in the Health and Safety at Work Act (cited in Bust et al., 2008).

Phua et al. (2010, p. 418) claim that "managers rely on multilingual supervisors, workers and alternative language signs". Some contractors in their survey would not discuss work with foreign nationals unless there was an interpreter, but the main interpreters were "the supervisors of subcontracted workers". Yet, 31% of workers said that they did not interact with those from a different ethnic background and "32% of operatives and 21% of supervisors believed that different groups should stay away from each other on construction sites" (Phua et al., 2010, p. 416). The percentage of supervisors supporting that belief is exceptionally high, but it is important to understand that the study was undertaken in Australia and that in this group of workers, there were many Australian members of the labouring team who may have been more intolerant of migrant workers, who did not understand English, working beside them. In KSA, very few, if any, Saudis work in this capacity.

There are other safety considerations, apart from the obvious ones of working as part of a team but not understanding each other perfectly or the rules of engagement. There may be majorities speaking together in one language, perhaps laughing and joking while in the company of others who do not understand but might assume that they are being talked about. There may be social difficulties among members of the team, as some from the same background and culture may form what is known as an "in-group" (Tajfel, 1981), leading to others feeling disrespected and resentful. This can create arguments and even intergroup fighting. There may even be personal security issues because of the language barrier. If one signs a document that is written in a language one does not understand, then it is unlikely that the terms of the document are known in full to both parties.

The language barrier is a real problem if a construction site wishes to increase measures to improve H&S awareness. Yet, the situation is not as negative as might be thought and new research points to some positive considerations.

2.6 Positive Ways Forward

There are steps that can be taken towards creating a safety culture on construction sites, even those sites that are environmentally, personally and physically considered the most challenging – those using a migrant and multilingual workforce. The first one is that although these issues discussed may weigh heavily on the operative and labouring workforce, recent research suggests and agrees, that the establishment of an H&S code that works for all is successful when management takes this as a priority. The message is that if managers can understand H&S needs and implement a procedure to put best practice into effect, it is likely to succeed. Arastoo et al. (2013), Alasmari et al. (2012) and Awad (2013) all highlight the importance of H&S issues being understood and communicated by management to the entire workforce. It seems to be important for management to take the lead in establishing H&S programmes, based on best practice, which is supported by current research. This is seen as the most productive and effective route.

There is another step that can be taken; it is hoped this will be supported by this current research study. What has arisen through this first part of the review is to identify what questions need to be asked of contractors who play a part in KSA's future growth and the regulation of its building industry. These are the questions chosen, as they appear to reflect the concerns and challenges evident in a review of the literature. The important issues are to question whether those involved in the construction industry on a day-to-day basis hold similar views on H&S as those made evident in research studies. Therefore, the first three questions this study addresses are:

1. What are the current H&S practices in KSA construction sites?
2. What are the existing challenges in construction safety and health performance management, according to public sector construction contractors in KSA?
3. How can BIM enhance the continuous improvement of H&S on construction sites?

These questions are designed to produce a view on what is now the practice regarding H&S issues. Despite its leading position, in many respects the construction industry in KSA relies on outdated methods and practices that are losing their relevance in this world of globalisation, migration and communication. The easiest way to facilitate a H&S programme in Saudi construction sites may be through the use of technology of various kinds. Visual presentation cuts across the barriers of language, but perhaps video screens in the workplace or hand-held technology may produce the safety message in a visual, non-verbal and, therefore, non-threatening way. New technology can cross the barrier between management and worker and offer instant translation. Workers can also perhaps use translation technology to remain in touch with each other. It is surprising that KSA has not yet fully accepted the opportunities that technology can offer to the current workforce and play to the strengths of a multicultural workforce.

With that in mind, the literature review now moves to examining the literature on BIM as the subject of the final research question in this study – how can BIM enhance the continuous improvement of H&S on construction sites?

Chapter 3. Relevance of BIM for Enhancing Construction H&S

3.1 Introduction

This chapter introduces the role of ICT in enhancing safety and reducing hazards in the construction industry, as well as the benefits of BIM that has become widely adopted in the world. The relationship between BIM and H&S in the construction projects is also discussed, and the involvement in current construction projects is not enhancing H&S.

3.2 ICT's Role in Enhancing Safety and Reducing Hazards

In the previous section, it was noted that the main problems facing the Saudi construction industry are: failures in identifying hazards on construction sites; delays in building projects that cause careless attitudes to develop in the haste to catch up; and the problems of communication between and within groups in the industry, given that the workforce is multilingual and multicultural. One of the communication problems is that methods tend to rely on the written word. Section 3.1.1 discusses communication issues in the industry in KSA and the delay in take-up of technology. Advancements in tools and approaches can create many chances for the Saudi construction sector to better its current H&S framework. Regrettably, there has been an elevated annual accident and death rate in this country for a decade, and the need for a unified structure to H&S is very obvious. It makes sense to use ICT to aid in this goal, and the following chapter explores the mind-set and techniques used to accomplish this.

3.2.1 Communication and Technology

ICT has been adopted in the developed world to assist better communication and provide better cooperation between individuals and businesses. The manner in which building ventures work is that they inevitably comprise a large number and range of employees and interested parties who share information to lower the chances of accidents and injuries and encourage better choices being made with fuller, more detailed data. Despite this, there has not been a particularly big improvement in H&S within the construction sector, even with the advance and advantages of computerisation (Aguilar & Hewage, 2013). Therefore, pragmatic and useful technology is needed to begin rectifying this situation, at least partly.

Overall, the majority of building ventures in KSA use outdated and conventional approaches to the sharing of information and general cooperation at work. Alternatives include telephoning, faxing and using email to send or receive information or updates (Dave et al., 2010). Furthermore, in several building processes, these old-fashioned techniques are used for the sending or receipt of information, even in construction locations that are difficult to reach, with data that often takes a long time to unearth and process, or which may be extremely cumbersome to send physically (Bringardner & Dasher, 2011; Chen, 2008; Bowden et al., 2005). Additionally, Garza and Howitt (1998) point out that the traditional approach of using paper at the construction location means that the most up-to-date or urgent information cannot immediately be sent and received in the manner that computerisation allows; this creates both a backlog of paperwork – which, inevitably, may be irrelevant by the time it is actually received – and leaves the employees physically exhausted and drained from the burden of such paperwork.

Nourbakhsh et al. (2012) examine 22 nations' current communication technology for supervising locational data, as presented in Figure 3-1. It is observed that of the 99 responses received, the majority used mobile telephones, with a little over 22% comprising the use of Dictaphones, handheld cameras or walkie-talkies. Yet, a study of Saudi building firms (Sidawi, 2012) shows that 89% were utilising conventional methods of communication. As mentioned above, this could include the use of mobile telephones and faxing, but also location visits, regular updates being provided and meetings. Interestingly, though, it is noted that 93% of those responding did not utilise any mobile communication tools apart from mobile telephones (Sidawi, 2012). In contrast, it is clear that outdated paper communications are seldom used globally these days and Garza and Howitt (1998) suggest that this sort of communication at building locations is becoming increasingly less common.

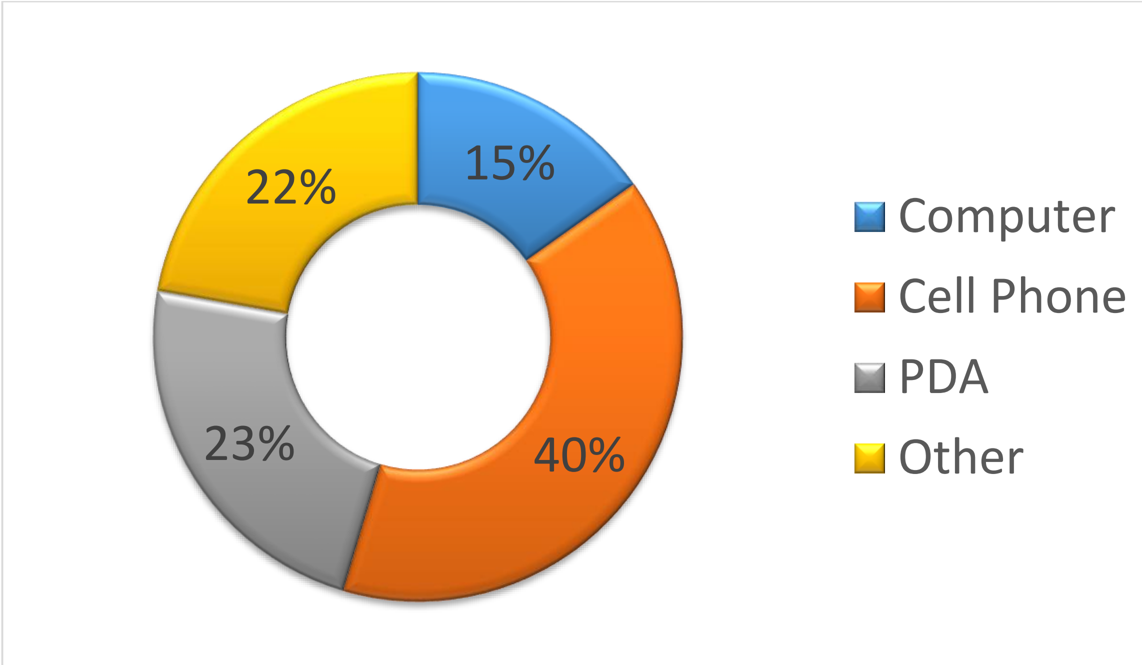

Figure 3-1: On-site information management tools
(Source: Nourbakhsh et al., 2012)

Over the last few years, there have also been rapid advances in mobile computing. This type of computing can be described as that which enables the owner to use their device in any location, or even whilst travelling between different locations, and without the need necessarily to be connected to a power supply or use a cable. Regarding smart phones, the Oxford English Dictionary (2013) describes these as "a mobile phone that is able to perform many of the functions of a computer, typically having a relatively large screen and an operating system capable of running general-purpose applications". Given their capabilities, memory and speed, smart phones are now essentially mini laptops (Muto, 2012), with the addition of GPS mapping, supremely responsive touch screens, cameras with pixels that match many high-end digital cameras and the capability of fast transfer of data. Furthermore, *Mobile Life* (TNS, 2012), a worldwide survey of 48,000 people across 58 nations, demonstrated the adoption and need of these high-end elements in the majority of modern mobile phone owners (see Figure 3-2).

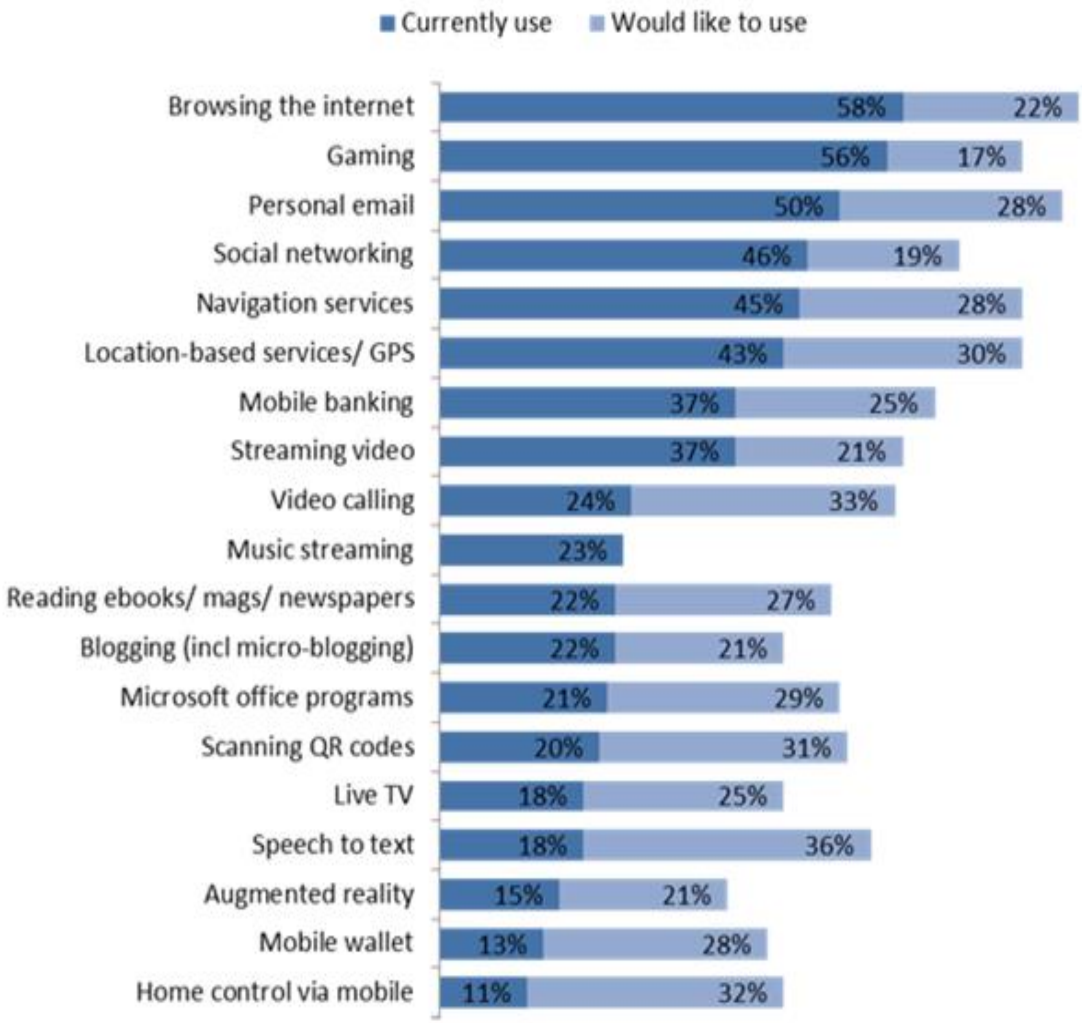

Figure 3-2: Use and desired use of smart phone features among all mobile users (Source: TNS, 2012)

Owing to the rapid advancements in smart phone technology, it is difficult to predict with any accuracy what will happen next or how the market may develop. Table 3-1 demonstrates the abilities of smart phones as they currently stand. Kim et al. (2013) observe that such advancement has meant the modern generation of contractors and employees can now use this technology for better supervision at the construction location and employ site-based ordering, real-time sending and receiving of data and digital imaging via the smart phone.

Mobile computing has grown hugely over the last few years. The overall mobiles' sector is one of the wealthiest and most successful industries of this generation, and Figure 3-3 shows how it is now second to the electricity and marine sectors in the generation of wealth. In 2012 alone, the worldwide mobile sector created US$200 billion – 35% more than that of the world's mining industry (GSMAK & Kearney, 2013). GSMAK (2013) observes how during the last five years, the number of individuals purposely purchasing or at least using mobile devices in developing nations has grown at an annual rate of more than 10%.

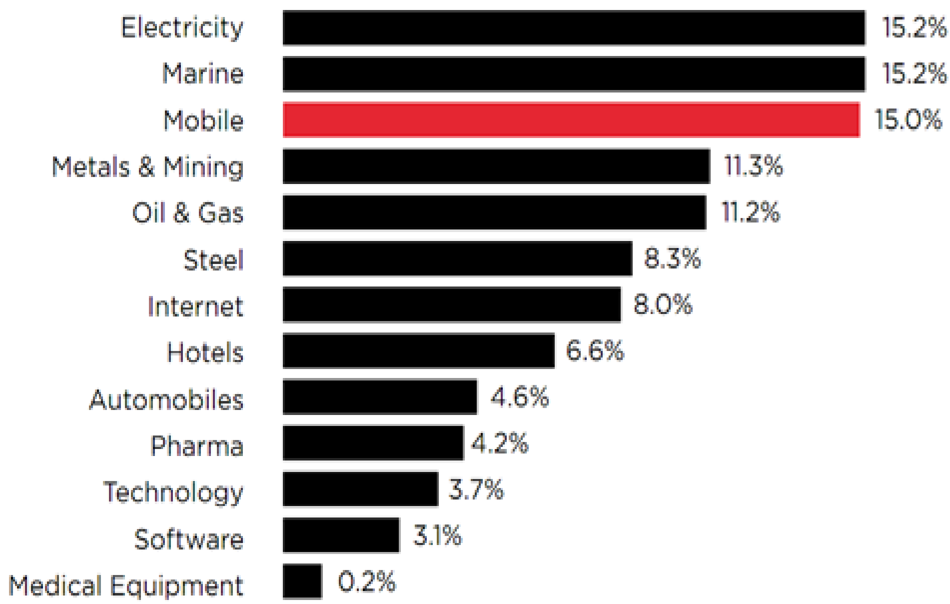

Figure 3-3: Capital expenditure across a selection of industries
(Source: GSMAK & Kearney, 2013)

Furthermore, GSMAK and Kearney (2013) suggest that data is the primary factor in this global expansion, owing to the very high level of mobile broadband data being exchanged. This has increased by 100% year on year, rising to 1,577 petabytes each month of 2013. As provided in Figure 3-4, mobiles are usually utilised by several sectors to improve consumer access to their most important services – this is seen in banking, utility service provision and billing, and even in the provision of healthcare and education.

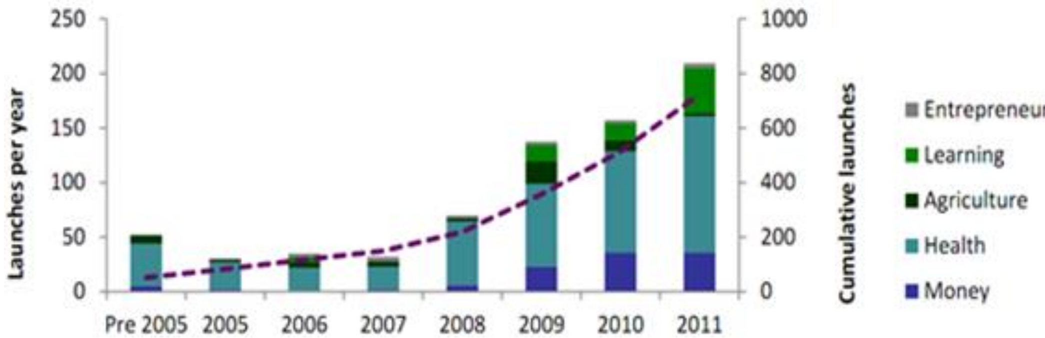

Figure 3-4: Mobile-enabled products and services in the developing world
(Source: GSMAK, 2013)

In other sectors and in other nations in the developing world, as in KSA and its construction industry, insufficient knowledge of the potential utility of mobile uptake can still be observed. This could be generalised into three primary elements:

1. An insufficiently specific value chain that is an established value for users in every phase of this process – for example, the service providers, retailers or mobile operators
2. A maintainable corporate framework that provides the service but is also capable of becoming independent
3. Being seen in different markets or industries with the understanding of parallel associations within that sector and the capacity to link to areas that can grow the worth and reach of the service

3.3 BIM

The delay in take-up of cutting-edge technology in KSA means that technological advances are not readily understood or fully utilised. Within the architecture, engineering and construction sectors, there has been rising support for the use of BIM, as part of the construction process. Difficulties in the area of design bid and build have caused the continued development of methods that aim to facilitate quicker and more practical ways of creating, constructing, developing and managing construction projects. Simplifying the project by pre-construction in a digital form could be the answer, as possible hazards, shortcomings, schedules and costs can be identified and clashes detected.

BIM is a form of computer-generated design. However, CAD tended to be 2D originally and was created in the form of drawings that sometimes contain human error. This design may not have meshed well with the engineering, or the construction, leading to enforced delays. Additionally, it is difficult for even an experienced contractor to identify hazardous possibilities from a 2D drawing. BIM works on a minimum of 3D, in a form of parametric modelling that can create a virtual representation of the design and can incorporate all the engineering material, too. To create this model, there is a need for designer and engineer to work cooperatively, leading to all considerations of the build being discussed, including how it will be run and even decommissioned (Kymmell, 2008). For projects that dispense with the bid element of conventional tendering in KSA, the contractor can also be involved. Specifications can be agreed upon and any challenges jointly discovered. Furthermore, regarding the viewpoint of accepted global guidelines, BIM comprises both the real and utilitarian elements of a building venture, upon which accurate and thus advantageous decisions can be taken. In addition to these advantages, the model can include a fourth dimension (4D), that of time taken for the elements of the build, the building construction information model (BCIM), Specifically, it is one of these additions and helps to plan a timescale for the project. This timescale can be regarded as one of the many products of BIM, and similar products like a fifth dimension (5D), that of costing, can be integrated. The awareness of both timescale and projected costs could ease the challenge of delays in KSA construction business, as it provides the opportunity for time and funding management before the build begins, in an integration of drawing and virtual modelling, with schedule and costs.

The modelling itself can be described as being part of the overall construction process, as it is contributing to the operational process in a vital way (Wong et al., 2009). BIM purely emphasises the earliest stages of development – the designing, conceptualising, engineering and wider aspect of amalgamated provision of construction ventures (see Figure 3-5). Over the last few years, study in this area has moved from the previous "life cycle" stages to one looking at building upkeep, renovation and dismantling, including "end of life" concerns, especially in regard to highly complex buildings that require special attention and skills (Li et al., 2012). The possible applications of BIM could facilitate total infrastructure development and management.

Figure 3-5: BIM life cycle
(Source: Green BIM Engineering)

BIM is able to offer the provision of possible data to the contractors or other employees, so that they better understand their role within the project; furthermore, if one or more individuals believe there ought to be modifications or additions to the modelling, then the software used is able to alter the model quickly and easily. Over time, leading companies are increasingly using BIM to facilitate improved cooperation. Joint working has become essential for any building project and for contractors it is now a vital element of their work. It is highly advantageous during any of the stages of construction, from the earliest tendering and pre-production through to the work itself and even its follow-up procedures, that construction, in particular, should respect and include all parties in making decisions.

As explained above, BIM is utilised to enhance the devising of a project, its design and the building itself. This type of design involves the formulation and imaging of building ventures through the use of unified and interrelated assessment modelling, and it is very useful in assisting construction projects in both the public and private sectors (Jannadi & Assaf, 1998). BIM also comprises numerous additions that provide the contractor with a deeper comprehension of the venture. Such integration of the modelling products is extremely advantageous, as it enables the creation of a more comprehensively detailed process and set of specifications than might otherwise have been possible (Group, 2014). The older systems did not offer contractors and their employees such precise knowledge; therefore, the process and outcomes of current construction projects could, in theory, be improved with the utilisation of BIM.

Building information models are fed designated aspects of the project and are then able to formulate these into procedures and results. Such a list of procedures and expected outcomes provides information at every stage involved, such as mandatory and fundamental requirements, the timescale of the project, the materials needed, mathematical data and quantity take-offs. Whenever required, any of this information can be input, altered or totally removed, and any one of these actions are extremely important to the creation of the ultimate design and construction plan and, therefore, its anticipated execution (Alasamri, Chrisp, & Bowles, 2014). When creating a building information model, all required elements of the contractor's needs are fed into the system.

The construction outline is noted before the contractor's specifications are added to it. The construction outline, for example, will often explain what sort of structure is to be erected and its location, but the specifics of how it should be constructed, with what materials and the anticipated timescale are usually provided by the contractor, in a DBB model particularly. Through the merging of a data, the computer will produce a model that enables the contractor's labour force to see and comprehend the project with clarity ahead of time. This modelling, if acknowledged and adhered to at every stage, will make sure that there is no limitation of space in which to operate and that all employees have ample space and are given a personal schedule of works. In each stage of the construction, a building information model outline will be created that correlates to the specifications.

This outline is presented as an image, table or a graph that displays every stage visually, so that each and every employee fully comprehends the desired aims and outcomes of the project. The outline framework may comprise various stages, including the design, construction and overall running of the project. Once every element of the venture has been achieved, the building information model outline will assist in accurately describing every stage involved, the timescale of these individual elements and the overall project (Li et al., 2012). Furthermore, if

BIM pays specific attention to the overall running of the project – that is to say, its managerial and supervisory areas – in combination with the details of the building site itself, this provides additional important benefits, not least the ability to exert better command and observation over the project. Autodesk (2012) presents the benefits or adopting BIM to help better choices be made, including aspects such as the development and research into other possibilities, and their being examined, particularly in relation to a comparison with the specified aims, knowing the impact of trade-offs and utilising the findings to discover reliable solutions.

As construction gets under way, the contractor needs constantly to input new data into the model as employees, architects and/or engineers provide updates on the stages of construction. For example, this information may necessitate certain materials or machinery, or an alteration to the speed of the work. Overall, this sort of data could be crucial both to the project's initial calculations and anticipated timescale; additionally, it could help to formulate several requirements that emerge during the work itself. It is interesting to note, too, how BIM provides an alternative set of concepts or theories in the architecture, engineering and construction industries, especially when these improve the roles or responsibilities of stakeholders. It has the capacity to provide efficiency and integration between stakeholders who, prior to this, may have been adversaries (Salminen, 2011).

Circumstances that heralded this development can be found in BIM's adoption across much of Scandinavia – Norway, Finland and Denmark – with the same being somewhat true of Singapore, which greatly supports its state-sector construction projects. These nations have the luxury of average populations and geographical area and, therefore, their administrations are able to enforce their plans nationwide more easily than those with a large population and/or a vast geographical area. More importantly, however, these nations are both highly developed and extremely skilled with mechanised and automated production systems, which are utilised in house building, as well as the building industry in general (Wong et al., 2009). The benefits of BIM, as highlighted in Figure 3-6, are best suited for such an environment.

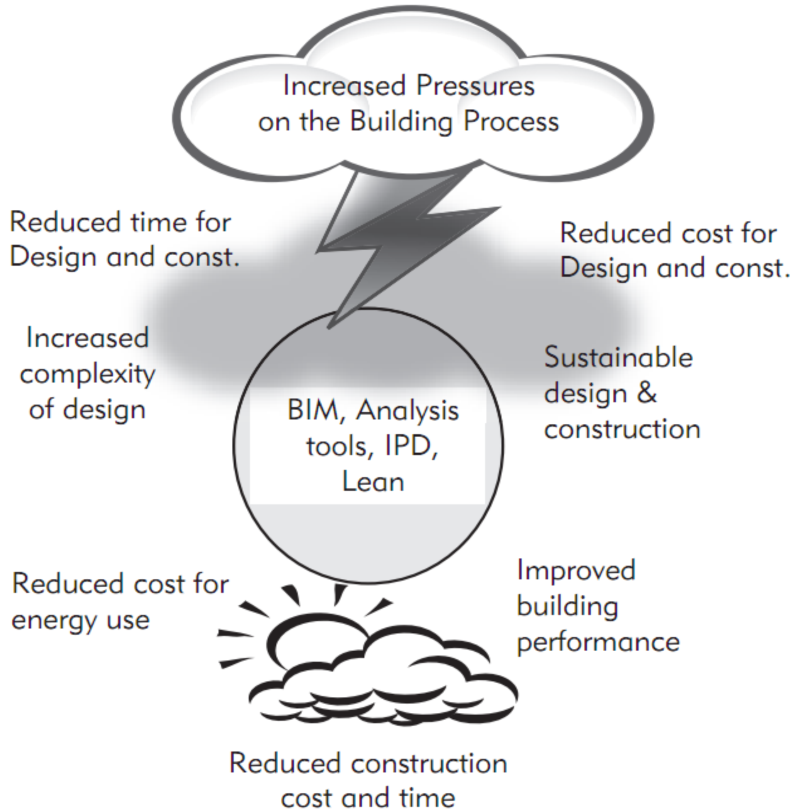

Figure 3-6: Benefits of BIM

(Source: Eastman et al., 2011)

Full and thorough utilisation of BIM, it is suggested (BIM Task Group, 2012), can also move the UK into a highly modernised era of building projects and help turn it into the epicentre of BIM. However, the adoption of BIM is a very complicated area and needs wide-scale support, integration, good relationships and clear aims and specifications, in order to be truly successful. It is important that this support comes from both the private and state sectors. Needless to say, government backing is a vital factor in BIM's adoption or chances of successful use. However, despite this type of support being a critical factor within the sector, one cannot say with certainty what its benefits would be, as the exact state of the sector is unknown. Interestingly, such backing is widespread in the formulation of an atmosphere that improves the H&S elements within the adoption of new technology in BIM formulation.

The UK government regards international collaboration in BIM as bringing both advantages and disadvantages. Experts in this field have explained that the main hazards are to be found in the tendency of adaptable and technologically sophisticated nations to “leapfrog” existing hardware and software and improve on the original model, thereby dominating the market. The retailing of both the BIM operation system and the hardware that utilises it is conducted in a recognisable global framework that is subject to the known advantage but also disadvantages of a market-driven neoliberal economy. Although the operating system is, by nature, very adaptable, the sector will always have the ability to impact on and profit from its evolution or modification. None the less, it would serve as an aid to increasing the country’s competitive nature if the UK expanded its use of the latest modifications to BIM, in order to enable what is called “lean construction” in the public sector (Cabinet Office, 2011).

In comparison with state-run projects, the huge support the private sector has afforded BIM is founded on nationwide schemes that aim to generate fresh business strategies and improved association between the relevant parties, rather than, it is hoped, encourage competitive tactics. The involvement of the private sector could undoubtedly improve the formulation of strong and vital business implements that may be utilised in the design of new operating systems and technologies for BIM. It is important to understand, however, that the committed backing of the state sector could well be required, even when a country has an equally strong and influential private sector supporting nationwide BIM adoption. This understanding suggests that weak or limited backing from either of these two sectors will not necessarily facilitate successful adoption of such modelling. In other words, it is only with the strong and consistent support of both the public and private sectors that the implementation of BIM stands the best chance of being successful and proving beneficial to the architecture, engineering and construction industries (Wong et al., 2009).

3.4 BIM and Safety

Using BIM in building project H&S considerations has been suggested by numerous academics (Eadie, 2013; Yalcinkaya & Arditi, 2013). One piece of research, in particular, argues that there are data suggesting that adopting BIM may assist in H&S frameworks (Wan et al., 2013). Academics in this discipline have shown that BIM is suitable for use in computerised safety assessments founded on current safety criteria (Melzner et al., 2013a; Zhang et al., 2012). Efforts are currently being made for companies to utilise BIM officially when formulating their projects' H&S frameworks (Melzner et al., 2013b; Zhang et al., 2012). BIM has been utilised for H&S education and to demonstrate the dangers within the context of digital imagery (Chen et al., 2011), but has also been adopted in the planning stages of ventures in order to lessen the risk of accidents or mishaps in the physical building stages (Qi et al., 2013). Regrettably, over the last few years, the building sector has seen more employee deaths or serious injuries than any other area of the private sector. This is due in part to developers lacking detailed understanding of H&S considerations; therefore, numerous dangers can inadvertently be designed into modelling and planning diagrams.

Rajendran and Clarke (2011) show how the adoption of BIM could assist greatly in finding anchorage points to improve H&S. BIM utilisation, along with cloud computing software, has been recommended as a method of ensuring continued safety within the engineering and building industries (Bennett & Mahdjoubi, 2013). Furthermore, the use of such information modelling to examine the safety of employees in small workspaces is currently being assessed (Arslan et al*.,* 2014). When BIM is observed in the H&S environment, this is evidence both of its success and level of uptake by construction companies. Additionally, BIM adoption, such as digital imagery, is recommended by experts as a means of further H&S improvements in the building sector (Li et al., 2012), with the work of Cheng and Teizer (2013) and Park and Kim (2013) providing assessments of radio frequency identification (RFID) and digital imagery software's utility within H&S structures. As the adoption of BIM is becoming increasingly valued, and given the fact of its use in numerous areas of the construction sector, it is entirely logical for BIM to contribute to H&S considerations and regulation for all construction companies.

Studies appear to show the following areas as the primary factors of BIM in enhancing construction safety: BIM-orientated design, hazard assessment and H&S risk examination, with BIM assistance and 3D and 4D digital imagery for H&S induction presentations. Regarding BIM-orientated design, this aspect incorporates the construction area blueprint design and accident avoidance forethought. In many places – for example, Finland – this is mandatory. Moreover, BIM can be utilised to assist in the design and development of construction duties that aim to minimise certain hazards at the construction site. For hazard assessment and H&S risk examination with BIM assistance, the technology may be utilised for the assessment of potential hazards and dangers, either through traditional physical outlines and diagrams or, as anticipated in the next few years, more computerised hazard assessments at the design stage as BIM allows and take4s account of the entire construction environment. 3D and 4D digital imagery for H&S induction presentations are a step towards bridging the communication gap caused by verbal barriers. 3D demonstrations help with a clear explanation of each phase of building ventures, which is especially important when dealing with KSA's migrant workforce. Verbal direction and multiple interpreters can be substituted by digitally created visualisation in site induction. From a H&S perspective, such as presenting the upcoming task to employees, this could be outlining the safety rules and specifications for a particular stage or element of the project and an explanation of potential risks and dangers.

3.5 BIM: Pre-construction Considerations

This section formulates and outlines the research utilised in the creation of a unified BIM approach, in order to provide excellent H&S for all employees at every stage of the building process. It should be noted that this is also a great chance to enhance the H&S of the industry overall. Over the years, the building, engineering and construction industry has gradually become more complex and wide-ranging; therefore, BIM, as a vital resource that helps to ensure safety through the continuous and robust supervising of data and project management, is crucially important in the entire overseeing of all stages of a construction venture, whether this is the initial pre-planning or the very last phase (Skibriewski & Ghosh, 2009). Operating systems pertinent to a project's supervision had been utilised previously to assist managerial teams in the smooth operation of their building ventures.

Older BIM, known as object oriented modelling technology (OOMT), was first utilised as part of design planning work before its recognition led to its being used in both the engineering and construction industries (John & Ganah, 2011). Owing to the success and utility of OOMT within the design of architecture, it became more prevalent and adopted in construction itself. Moreover, as outlined by Khosravi et al. (2014), many chances to utilise BIM, the successor to OOMT, have been taken. Maloney and Cameron (2004) note how, in the UK, developers did not always have a full and thorough comprehension of their role in construction safety and, therefore, at times, failed in their duty of formulating and delivering the highest levels of H&S.

Moreover, they may have squandered the chance to adopt BIM within the safety frameworks, which in turn would have decreased the opportunities for technological development in devising H&S approaches, as well as preventing the assistance of developers, communication channels, the formulation of new danger supervision and the opportunity of there being novel ways to unify the physical side of construction and H&S dilemmas.

Currently, BIM has become a suitable and respected tool for all aspects of formulating H&S procedures and frameworks, especially in relation to building sites. Data relating to design and build can be presented and updated as BIM. Owing to its use of multi-dimensional data, an assessment can be undertaken on the real-time state of the project and, equally importantly, provide solutions to any issues relating to the construction itself, the speed with which the work was being complete, or the dangers that existed.

Many studies have shown that information modelling software can offer a fresh and modern approach to resolving construction site issues. Moreover, with this information being presented to every staff member regularly, overall comprehension of the hazards and dangers at various location can potentially be enhanced (Kiviniemi et al., 2011). Pre-construction preparation provides numerous opportunities to utilise BIM within the building industry and Figure 3-7 offers a good representation of this preparation. With this example, the project required the installation of building utilities; by being able to view all aspects of this digitally, staff could more clearly see the dangers and management decisions required to facilitate quick and safe delivery of the project.

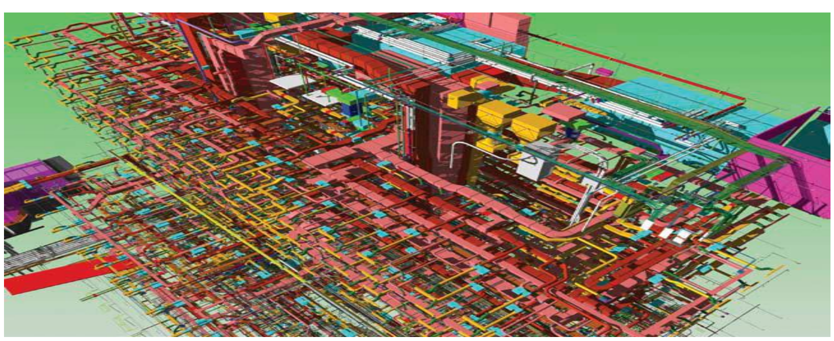

Figure 3-7: BIM showing all utilities

(Source: Rajendran & Clarke, 2011)

BIM certainly has the capability of being utilised in the H&S development stages, especially when these are related to building sites. The site teams will change regularly, owing to the differing needs and specifications of the project and the use of subcontractors with different areas of experience or expertise. In some ways, every building site is a unique entity that carries its own particular dangers and risk levels; new workers can join a team whilst lacking the full knowledge required to comprehend the potential dangers of that particular site. The safety approaches in use on site might not be sufficient to prevent harm, even though both the employee and their employer make the best effort to avoid such an outcome. Therefore, the early development stages of a build can offer the best chances to eradicate, or at least greatly minimise, dangers and risks before they have a chance to occur on an actual construction site. Prior study in this area suggests that there have been insufficient methods or mechanisms to help developers confront this problem (Ku et al., 2010). Kiviniemi et al. (2011) draws attention to the fact that BIM has essentially been able to create the desired structure digitally using computerisation, before the actual process has even begun. This facilitates predictions of issues and flaws and examines virtually the possible implications of all of these factors. It has the capacity to bring on board various streams emanating from specifications, timescales, environmental issues and the handling of machinery. Before the build is begun, turning spaces for cranes or dumpers, for example, can be factored into the likely site characteristics, so that operatives can be aware of hazardous areas and the space they will have to work in during different stages of construction.

BIM has the capability of being utilised during the building stage, too, thus offering a digital representation of the structure that matches the progress up to that point (Watson, 2010). The development of building and virtual reality can run side by side, so as the build develops, this is reflected in the changing representation available for all to see. New risks that might arise can be identified. Therefore, this modern capability does not merely offer vital software to construction companies that assists in the physical side of their work; rather, it can now provide enhanced fulfilment of a venture through its ability to help ensure hazards and dangers are minimised for all employees involved throughout the timescale of the construction (Ku & Mills, 2010). 4D digital imaging, adding the dimension of time to a conventional 3D design, has been shown to be an excellent method of presenting numerous development and building flaws or dangers, owing to its ability to present challenges that arise during the construction.

As Gibbs et al. (2010) explain, the building sector is infamous for its numerous hazardous and risky construction environments. Therefore, ensuring the highest safety possible on building sites is of vital importance for any construction firm and not just for the sake of individuals who may be harmed. An atmosphere of excellent safety breeds confidence and reassurance amongst staff and this, in turn, raises the speed and quality of the work undertaken (Zhang et al., 2012). Additionally, several studies suggest that targeted improvement of staff safety mechanisms at the actual time of the danger occurring can be adopted. Technology can pre-warn an employee of an imminent danger. As Giretti et al. (2009) outline, one example could be an audible warning sound that warns a member of staff that they are close to static electricity. Fullerton & Wempe (2009) suggests a real-time warning mechanism that uses its own initiative to foresee and alert employees to a particular danger or set of dangers that have arisen. Additionally, he claims that safety measures could be enhanced by the use of an after-the-event tool, which collates information for examination so as to understand better what had occurred in the hazardous situation and offers potential suggestions for future safety management.

Regarding 4D software, it can be utilised to connect a construction work’s remit in 3D with the anticipated building timescale, in order to present digitally the overall construction development. Labour tasks at the location can be generated into a 4D computer-generated model, where that created by the developer is adopted initially. Prior research in this field discovered that there are particular types of operational aspects at building sites, as outlined above; for example, certain movements like those of a tower crane, a cherry picker or the driving of trucks and lorries. As Zhang and Li (2010) note, this can allow the software to present the building operations more accurately and authentically.

An analysis of BIM was conducted by Harty et al. (2010) to understand better the ability of incorporating new software and technologies within a specific H&S aspect – the dangers of falling or tripping over an object. The use of 4D BIM methods could enhance H&S at work by better integrating the various problems at hand. Work related dangers and risks do suggest that confronting risks and dangers to employees in the development stage is a crucial element to decreasing the number of accidents seen in the building sector (Gambatese et al., 2005). In this development stage, adopting BIM can allow its potential on a construction venture to be utilised fully because its capacity to impact the expenditure is at its greatest. Employees can intuitively formulate methods and approaches to resolve problems before they even have the chance to destabilise the task. Achieving this requires the full understanding and support of every employee working on the particular venture and, understandably, it is absolutely vital to have an excellent working environment with high levels of cooperation. Without this, the aims may not be met and problems could still arise (Hergunsel, 2011).

The latest research into H&S has focused on how computer-generated imaging could be adopted as a way of unifying the issues found in the management by laws, rules and guidelines. As explained by Khosravi et al. (2014), BIM cannot merely be described as a computer package or operating system; rather, it is an entire digitally created mind-set and process that needs staff to operate within a pre-determined structure and adhere to its requirements. Productive adoption of BIM depends on three primary aspects: firstly, the creation of the knowledge and data; secondly, keeping this knowledge secure; and thirdly, utilising this data to produce the best outcomes. One of the most important worldwide outcomes is enhanced safety of construction sites.

As the build has been planned in detail and as all this detail has been holistically managed in BIM, it is possible for contractors to see the most cost-effective and safest practice for certain operations. It offers the possibility of prefabrication, which can eliminate many workplace hazards (Chelson, 2010). As the author explains:

> "Another saving due to BIM is improved safety brought about by the ability to prefabricate pieces that are safer to install and reduce work in hard to access places. Southland Industries reports that it is fabricating material at waist height in the shop and installing bigger pieces that cannot be picked up by one person. Therefore, proper equipment is planned for and used to hoist up the bigger pieces and the final connections are made in a safer way. The advantages of BIM in building H&S has been examined by numerous experts in this field" (p. 275).

The use of prefabrication is one that has rarely been exploited but could result in savings of safety, time and costs. There has been much research undertaken on the possibility of adopting the "Design for Safety" (DfS) initiative within BIM, with Taiebat (2011) narrowing the remit of the study to incidents of employees falling from a height. Using DfS, the study offers a structure by way of flowcharts to show the dangers and risks for potential use in updated information models. This would help software engineers implement danger and risk understanding into the system for future use.

A computerised safety mechanism was formulated by Zhang et al. (2013), designed with the capability of notifying building engineers, supervisors and the managerial team of all the specifics of the H&S aspects required and, importantly, how and why these are required, in order to reduce the risk of falls, prior to the construction work commencing. Benjaoran and Bhokha (2010) outline a framework of regulations that could quickly predict a height related danger or risk in real time and take the necessary steps to prevent this occurring.

Bust et al. (2008) point out that another challenge posed to the construction sector is that it does not have a rigid, pre-set flow of production and, therefore, may lack the ability to test the product – the building – before constructing it. However, many commentators have pointed out that BIM provides superb advances in this regard and can be highly beneficial. Researchers claim, therefore, that its adoption can offer the following advantages, as outlined above, including the following:

- Reduction of expenditure in development and utility, as this could be a seamless cooperative initiative involving all stakeholders
- Through the use of 4D digital interfaces, an enhanced understanding of all the stages of the build and their issues
- This offers the ability to foresee hazards and dangers at a much earlier phase of construction
- H&S dangers could be eradicated, or at least minimised, in the development stages, meaning that developers will not need to oversee dangers left over from a poorly executed construction stage

- The minimising of mistakes or human oversights could occur through the use of visualisation in both 3D and 4D
- The ability to solve problems or dilemmas prior to on-site commencement, to include, problems arising from hazards that might arise and, using 5D, costs that could escalate as a result
- The primary constructors having a full and thorough comprehension of the venture and its related aspects, whilst facilitating simple but thoroughly specified oversight and management of the entire construction task
- It stands to provide a necessary decrease in injuries and accidents. BIM is excellent in ensuring a lowering of the number of work related incidents and injuries. This is thanks to its ability to collate and update information to sites and their workers regarding the possibility of unforeseen accidents in real-time, thus enhancing both the construction site's H&S itself and the employees' understanding of how and why such an incident had been likely but was averted

3.6 Construction Safety Management by Visualisation for a Migrant Workforce

Flaws and inadequacies in the conventional, and now outdated, supervision of H&S has led experts to design novel methods and approaches for this area of construction. As discussed extensively in this paper, digital imaging is a key approach that has been examined by experts; a good outline of its advantages can be found in the work of Chiu and Russell (2010). Overall, BIM is a superb method for achieving this important visualisation, not only because graphically it is comprehensive and every employee can understand what he or she are seeing, but also because of its full and thorough analysis of the whole construction process.

Chiu and Russell (2010) argue that the adoption of visualisation tools can enhance communication between the employees and the choices they make, improve their understanding of the information provided to them and produce more thorough and detailed data, offer a better ability to understand and convey the data, reduce the chance of misunderstandings, convey the project's drift as regards time and budget, and examine the standard of the project timescale.

Furthermore, it affords the team a 3D image of the structure whilst also offering a clearer comprehension of how the completed structure will look. Additionally, because this digital imaging is able to be shown to both the developer and the proprietor, it means that all important parties have access to a tool that helps in the understanding of the project and in the choices made to decrease dangers and risks associated with the construction (Chiu and Russell (2010).

Hadikusumo and Rowlinson (2002) observe the chances of utilising a DfS technology to enhance understanding in construction's H&S, surmising that it can be achieved for the following reasons:

- The provision of 3D modelling allows the user to gain a simpler comprehension than that offered by outdated 2D graphics (see Figure 3-8)
- The computer generation of the building project's stages can teach users more comprehensively than conventional 2D graphics and writing
- The technology includes a pool of information that aids H&S developers and employees in recounting their past encounters regarding danger, risk management and implementation

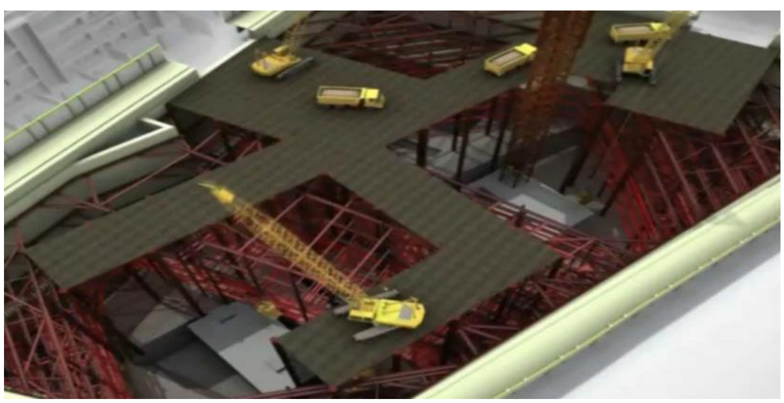

Figure 3-8: Hennesy Centre safety and site logistics planning
(Source: Cooins, 2011)

The current issues regarding anticipating danger and risk have been remarked upon by several authors, as a result of the continued use of 2D graphics and insufficient knowledge of the building development stages. Several experts recommend using digital imaging software as a means of solving this issue (see Figure 3-9). Chau et al. (2003), for example, argue that 4D presentation offers a more detailed and thorough understanding of such a project than conventional 2D graphics and timescales. Jongeling and Olofsson (2007) concur, noting that 4D imaging offers its clients a simple and comprehensible visualisation of the project's anticipated timescale, as well as assisting in the communication between the many stakeholders of the construction at hand. Thus, 4D BIM can also be adopted as a method to foresee dangers or risks that may arise during the work.

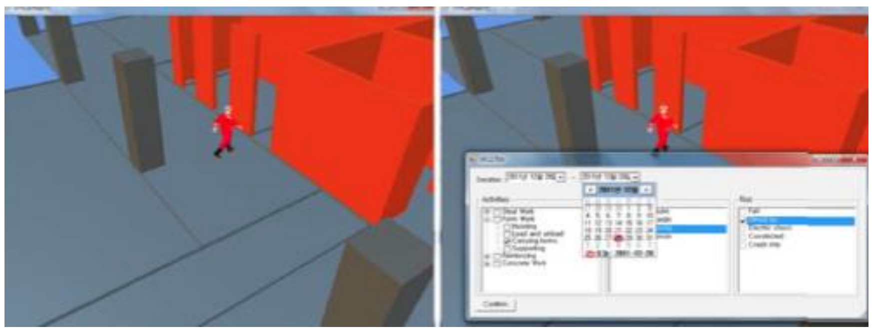

Figure 3-9: Visualisation of hazard identification using worker avatar
(Source: adapted from Park & Kim, 2013)

Using this data, short-term features like guardrails or danger signs can be input into the model, with the H&S aspects amalgamated into the timeframe (Hergunsel, 2011). Being able to see project data in this manner has previously been shown to be very helpful in the planning of projects and their supervision, and this has been demonstrated by the ubiquitous use of BIM within the building sector.

Owing to the uptake of and respect for 3D, 4D tools have become the ultra-modern technology to bring the project's information to an even higher level. Studies have shown the possibilities of 4D in building preparation and supervision; however, so far, this has mostly been adopted in H&S, rather than the construction stage itself. Furthermore, a method known as construction virtual prototyping (CVP) is adopted to show the utility of a 4D method for the digital imaging of project dangers at each stage (Chiu & Russell, 2010).

The work of Hadikusumo and Rowlinson (2002; 2004); Chantawit et al. (2005) and Benjaoran and Bhokha (2010) had, at the time of this study, failed accurately or thoroughly to visualise this development sufficiently. Through use of the CVP approach, the decision-making of construction industry employees and the projected building stages seen in short-term projects have been visualised for the first time. Computer-generating the actions of employees so intricately as part of H&S considerations enables better understanding of the dangers and risk levels posed by a hazardous work environment or hazardous decision-making in the development phase. As can be seen, this is highly innovative work in the building sector and is anticipated greatly to enhance the sector's understanding of dangers and risks.

But perhaps the greatest benefit to the Saudi Arabian construction industry is that BIM technology could better inform the migrant workforce that forms almost all of the unskilled and semi-skilled labour on construction sites in KSA and may encounter a language barrier. No research studies have looked a BIM as a possible aid to these labourers and, therefore, to the efficiency and safety of the country's construction industry. Poorly educated rural dwellers from South and East Asia and Africa may find the acquisition of a new language very difficult and the reading of H&S signage and induction material additionally challenging. In a study by Loosemore and Adonakis (2007), 13% of participants said that language was a barrier to H&S in the construction industry. Bust et al. (2008) echo this:

> Managers need to know how effective these (audio) visual communications are, there does not appear to be any sign that the methods have been evaluated. Indeed, research about communication and second language speakers in the construction industry found that supervisors were not aware that the 1996 EC Safety Signs Directive in fact requires employers to explain unfamiliar signs to their employees and to tell them what to do when they see a safety sign; word-signs were found on most sites and one site used only these (p. 589).

The Bust et al. (2008) study, in light of increasing globalisation in many industries, involved a wide-ranging survey of problems of communication for construction migrant workers in China, Hong Kong, Thailand, Nigeria, Poland, South Africa, India, the United Arab Emirates and Qatar. It aimed to discover how important information on H&S could be communicated, and it concluded that visual signage was mostly helpful and that interpreters, too, were widely used by construction companies.

Pransky et al. (1999) studied the occupational risks for immigrant day labourers in construction, noting that short-term work of this nature was often undertaken as an unskilled job in high-risk environments. They claim that levels of illness and safety knowledge were higher amongst those who could not understand the language, especially with signage, and who tended to underestimate and not report accidents.

However, a study by Hare et al. (2012) claims that pictorial aids might not be totally effective. The team discovered that of the H&S images it developed, 23 were not understood and that workers from India and Africa were more confused than those from European countries by the meaning of images. The use of visual imagery has been thought to aid understanding of complex issues for those with language difficulties, but it may be that there is a cultural or dimensional problem in the use of 2D imaging. Some cultures, for example, have problems in understanding emoticons. It is possible that migrant workers in the construction industry may need to use what the Bust et al. (2008) study terms “experiential” knowledge gained in their everyday work on a number of different construction sites over time. Those authors refer to a study by Pink (2004), who suggests a video-tour approach may be better suited to create an awareness of H&S issues for those with limited language skills.

This is, in fact, a use for BIM that has not as yet been studied in Saudi Arabia. BIM could be used as a virtual reality system that migrant workers could “walk” through. In this way they would use the experiential knowledge that it is said that they largely rely on. They would also be able to judge the area in which they can work, the timing they need to adopt, the areas where hard hats and boots will be used, and they can note the provision at design stage to avoid accidents like falling from heights. BIM provides the workers with the actual experience, rather than inductions in a number of different languages, interpreters and 3D images that they may be culturally unfamiliar with.

Chapter 4. Existing Frameworks of H&S Factors

4.1 Introduction

Chapters 2 and 3 have reviewed literature on H&S and BIM, respectively, and related it to the stated research problem regarding the H&S issues in KSA construction industry. Although the findings of the literature review that BIM has the ability to enhance safety and reduce hazards in the construction industry. BIM, for instance, could improve H&S across many industries, but in the construction industry in particular. Moreover, these findings are tied to specific needs of KSA, based on economic standing and construction industry growth, as well as characteristics of KSA construction employees. In identifying both the vulnerabilities of KSA construction industry to H&S issues and the value of BIM in addressing many of the known issues in the construction industry, the findings of the literature review demonstrate the need for this present study. Essentially, it is known that BIM has value for improving H&S environments and it is also known that KSA has to address H&S issues in its construction industry. The purpose of this study is, therefore, to assess the intersection of these concepts in assessing the current use of BIM in KSA construction industry, in order to build upon the literature reviewed.

4.2 Conceptual H&S Framework

H&S regulation, requirements and recommendations in developed nations usually contain most of the following current elements within the remit of a H&S framework:

- H&S guidelines issued through all industries
- Training frameworks established, inspected and examined with designated trade requirements
- Practice codes established in agreement with professionals and workers in the industry
- An awareness of hazard situations understood and communicated throughout the workforce
- Regular site inspections carried out though the industry
- Safety equipment made mandatory
- Information and guidance provided by a central trade body

- KPI agreed on, established and integrated into performance assessment
- Regulation, where it applies, can be backed by legislative powers if necessary
- Medical care and first aid supplied on site
- Management-worker communication on all safety issues, including safety notices and signage, safety warnings, safety meetings, safety equipment supplied, lines of communication established if emergencies should arise
- Awareness by labourers of the layout and accessibility of the site
- Site kept clear of all hazards
- Training on the operation and maintenance of all machinery by those who might operate it

Ng et al (2005) provide frameworks of H&S factors for both the organisational and the project level (see Figures 4-1 and 4-2). These frameworks demonstrate the factors associated with the development of safety systems, safety procedures and practices, the establishment of safety policies and committees, communication of policies, monitoring of policies and participation of all stakeholders.

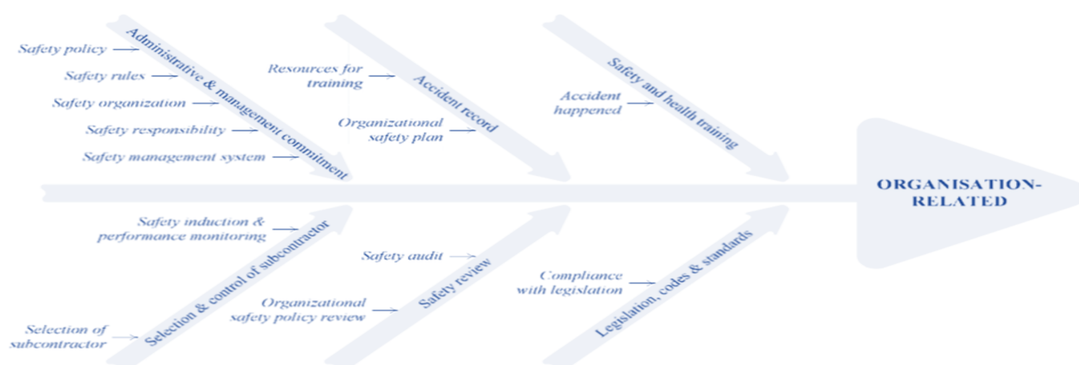

Figure 4-1: Organisation level H&S framework

(Source: Ng et al., 2005)

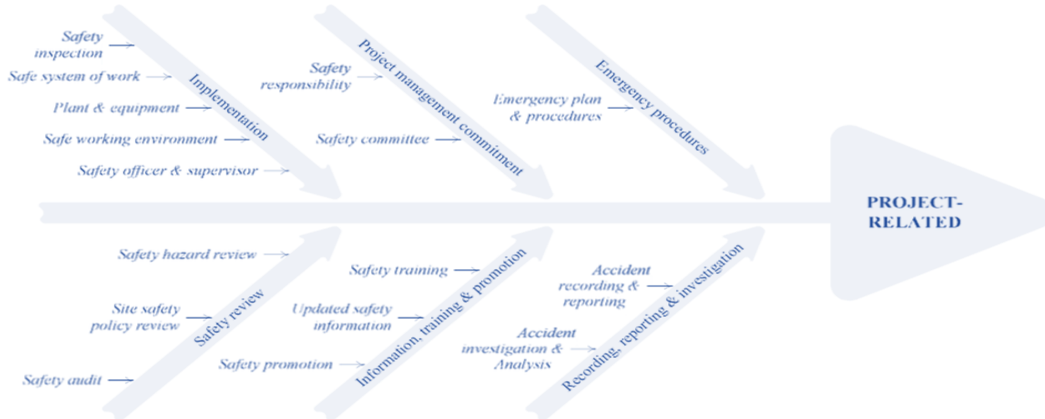

Figure 4-2: Project level H&S framework

(Source: Ng et al., 2005)

At the organisation level, this framework presents the following factors of importance for H&S (see Table 4-1).

Table 4-1:Tabl: Key Health and Safety Factors (adapted from Ng et al., 2005)

Main H&S Factors	Sub H&S Factor
Administrative and management commitment	Safety policy
	Safety rules
	Safety organisation
	Safety responsibility
	Safety management system
Selection and control of subcontractor	Safety induction and performance monitoring
	Selection of subcontractor
Accident record	Resources for training
	Organisational safety plan
Safety review	Safety audit
	Organisational safety policy review
Safety and health training	Accident happened
Legislation, codes and standards	Compliance with legislation

Next, each of the factors presented in the above framework is further explored through Table 4-2, demonstrating how each is defined within this research and how the authors addressed them.

Table 4-2: Relation between H&S factors and literature (Ng et al., 2005)

H&S Factor	Meaning (adapted from Ng et al., 2005)	Governing Literature
Administrative and management commitment	H&S must be priority at the administrative level to have measures effectively implemented at the policy and project levels. Commitment on the part of management includes safety policies, rules, organisation, responsibility and a management system.	Baxendale and Jones (2000); Abudayyeh et al. (2006); Anton (1989); Ng et al (2005); Choudhry et al. (2007)
Selection and control of subcontractor	Policies and practices must also consider the control of H&S in subcontracting selection and training.	Ng et al (2005); Pink (2008); Phau et al. (2010); Al-Khalil and Al-Ghafly (1999)
Accident record	To monitor and improve H&S, it is important to keep a record of all construction related accidents, including a system for accident recording and reporting, as well as conducting investigations to analyse the accidents.	Ng et al (2005); Lin et al. (2014); OSHA (2002); Lawton and Parker (2002)
Safety review	Safety should be monitored, even when accidents do not occur, through frequent and regular safety audits of the safety management policies and system implementations, which includes organisational safety policy reviews.	Lin et al. (2014); Aksorn and Hadikusumo (2008); Abudayyeh et al. (2006); Ng et al (2005)
Safety and health training	To communicate H&S policies and best practices to all involved actors, companies must incorporate training programmes and methods for communication between trainings.	Kartam et al. (1998); Hallowell (2010); Sulankivi et al. (2010); Berger (2008); Arastoo et al. (2013); Alasmari et al. (2012); Hassanein and Hanna (2008); Awad (2013); Abudayyeh et al. (2006); Ng et al (2005)
Legislation codes and standards	Governments must provide H&S oversight and companies must comply with occupational H&S legislation, codes and standards.	Ng et al (2005); Cotton et al. (2005); OSHA (2002); Anton (1989)

(Source: Ng et al., 2005)

These factors are presented in order of importance for impact of H&S, with administrative and management commitment designated as the most important factor for ensuring H&S, which aligns with the findings of Toore & Ogunlana (2010) and others. The measures associated with each of these factors are outlined in the next section as KPI needed to implement the factors in the framework for optimal outcomes.

This framework (Ng, et al., 2005) provides insight into the KPI that are essential to the development of H&S policies in KSA. These indicators have already been proven to be effective at keeping those working within the construction industry safe, so it only makes sense that they are used as the basis for H&S policy creation. The indicators are introduced in the order of performance designated in the framework, beginning with administrative and management commitment. A seventh dimension has been added as the final sub-section to introduce the role of BIM to the framework factors as an additional performance indicator.

4.3 Administrative and Management Commitment

H&S is viewed within the literature as a top-down process. Thus, it is essential for action to be taken at the administrative level to improve H&S outcomes. If managers can understand H&S needs and implement a procedure to put best practice into effect, it is likely to succeed. Arastoo et al. (2013), Alasmari et al. (2012), Hassanein and Hanna (2008) and Awad (2013) all highlight the importance of H&S issues being understood and communicated by management throughout the workforce. This relates to the ability of managers to respond to key issues in a timely and effective way. A widely held view is that most accidents are not instigated by an inconsiderate or thoughtless workers, but rather through the failure to be largely in control, which can be eventually blamed on the management of a project (Baxendale & Jones, 2000).

The roles and responsibilities of stakeholders (e.g. construction manager) cover a wide range of areas in the construction process. Management should ensure that sufficient resource is allocated for safety activities and that regular safety meetings and training are in place (Abudayyeh et al., 2006).

H&S in construction has been described by a number of researchers as the carrying out of work duties and activities following H&S guidelines that are aimed to minimise or remove hazards in the workplace. For example, Anton (1989) states that the adoption of H&S practices is decreasing work related injuries in the workplace by regulating working conditions.

Management must seek to change the safety culture in order to impact H&S outcomes. According to Phillips (2005), behaviour can be defined as the approach people take in situations when they are exposed to the effects of the outer environment. In the case of the construction industry, Lunt et al. (2008) report that to alter people's behaviour, barriers should be overcome, including complex work settings and the diversified aspects of the construction site, which can be home to a mixture of cultures and tongues. Despite this diversity, the senior members of the management team can be extremely influential and inspirational in terms of maintaining a positive attitude about H&S behaviour, an absence of which can lead to adverse effects. In fact, unsafe work behaviour can result in around 80%-90% of all accidents (Phillips, 2005). As such, a behavioural approach has become of a particular importance in dealing with safety issues, as it sheds light on the psyche of the workforce in the workplace.

One area in which management must seek to impact culture and improve H&S outcomes is incident reporting. As learning from H&S incidents is key to improving the quality of life of those working in KSA construction sector, administration must seek to promote an incident-reporting culture, which also aligns with the accident record component of the above framework. However, research suggests that as human error is a factor in about 80% of accidents, there is a complex culture surrounding reporting, as this can often imply wrongdoing on the part of the reporter (Lawton & Parker, 2002).

4.4 Selection and Control of Subcontractors

KSA regulations provide that the lowest construction bid is accepted and secures the contract (MFNE, 1985). Projects generally employ numerous different subcontractors in the construction phase, the result of which is that there is often a lack of oversight of the H&S policies and measures adopted by these subcontractors. For this reason, Ng et al. (2005) argue that it is important for management and administration also to consider oversight of subcontractors, both in selection and management, in H&S policy and implementation. This might include training and communication being delivered in the same manner as the company would do internally or it could take the form of including H&S considerations in the selection criteria, such as ensuring the subcontractors have their own H&S policies and implementation system, as well as ensuring they are in compliance with any established legislation.

4.5 Accident Record

It is imperative to keep a record of accidents to understand vulnerabilities and the procedures needed to reduce these accidents. There are trends in H&S accidents that are important to note for improving outcomes. For instance, falls are the cause of many serious injuries and deaths. More than half pf falls in construction are related to environmental factors, involving to some extent the working surface or facility layout conditions. Inadequate or inappropriate use of fall protection PPE and removed or inoperative safety equipment contributed to more than 30% of the falls (Huang & Hinze, 2003).

For accidents, many factors should have recorded, such as the nature of the accident, details about the firm and the work site and precautions that were taken to prevent the accident. Smaller sites also showed problems with health and welfare and in safety administration. Al-Haadir and Panuwatwanich (2011) quote Berger's (2008) results that 25% of construction sites surveyed provided no PPE. In a similar study to that conducted by Janaddi and Assaf (1998), Kumar and Kumar (2012) reported that in their study, of construction sites in Sri Lanka:

> "Usage of personal protective equipment is very minimal. Helmets are not familiar in most of the sites. Awareness among the workers regarding the usage of PPE is lacking. The contractor / employer is not providing the PPE to the labourers at their site. In some sites, even though workers are provided with PPE, workers are not using it properly. For example, workers are using their helmets for storing and carrying oil" (p. 30).

Huang and Hinze (2003) lay the blame for accidents on problems that could be averted with a properly managed code of practice and H&S training. They cite a lack of proper training, inadequate safety equipment and poor enforcement of safety requirements as major causes of accidents. Trends in these factors should be indicated in the reporting process to implement risk averse policies.

4.6 Safety Review

Regular site safety audits are orderly and feasibly independent investigation to decide if operations and related findings comply with scheduled measures and whether these arrangements are carried out effectively in a manner that is appropriate to meet organisational goals and objectives. Reviews of system management safety (SMS) audits should be carried out at least once a year to identify each of the critical elements of the SMS and decide whether matters are going well and if any changes need introducing. The major aim of the research was to provide a method to be utilised by inspectors within the construction industry in assessing H&S performance/improvement over a period of time within a specific sector.

In the US, safety regulations, in particular the "general duty clause" from the Occupational Safety and Health Administration (OSHA), require that employers provide their employees with safe and healthy working environments, free from recognised hazards. To meet this requirement, contractors typically adopt a mix of safety approaches, such as regular safety meetings, substance abuse programmes, task-specific safety training and pre-project safety planning (Lin et al., 2014)

Aksorn and Hadikusumo (2008) suggest that safety inspections are very effective in preventing accidents. In any given working environment, safety inspection teams in the organisation should identify a number of hazards that have to be tackled. In addition, the chief contractor/construction manager should carry out and note down the results of regular daily and weekly safety inspections of the work site that can be either formal or informal, in order to ascertain the legality and consistency of practices and those of the subcontractors/trade contractors employed by the organisation. For inspectors to make the most of these benefits and to maximise their potential, a methodology has been introduced to address the current inspection practices and operations from an organisational point of view. This tool is intended to offer a structure for full utilisation of the current inspector's skills, knowledge and experience. Through an approach grounded on skills and experience, one can rest assured that the measures chosen will be not only significant but also wide-ranging.

Proactive approaches to H&S could identify risks before accidents occur. In developing countries, the first step to the creation of an acceptable H&S framework in the construction industry is to be proactive and protective, not reactive and restrictive. Information modelling has been utilised for H&S education to demonstrate the dangers within the context of digital imagery (Chen et al., 2013), but has also been adopted in the planning stages of ventures in order to lessen the risk of accidents or mishaps in the physical building stages (Qi et al., 2013). Regrettably, over the last few years, the building sector has seen more employee deaths or serious injuries than any other area of the private sector. This is due somewhat to the developers lacking detailed understanding of H&S considerations and, therefore, numerous dangers being inadvertently designed into modelling and planning diagrams.

4.7 H&S Training

According to Kartam et al. (1998), in most developing countries' construction sites, there are no training programmes for staff and workers. Therefore, no orientation for new staff or workers is conducted, no hazards are pointed out and no safety meetings are held. Employees are left to learn from their own experience and mistakes. In order to reduce the frequency and severity of construction accidents, firms implement safety programmes and procedures that include written safety plans and training (Hallowell, 2010). Nevertheless, lack of safety training and practices were identified as key factors behind many construction accidents (Sulankivi et al., 2010). New employees usually come on board without prior knowledge of hazards they may face during the work on a construction site. A recent study on safety among many construction projects across KSA shows that 38% had no trained safety personnel (Berger, 2008). A highly trained workforce can operate in a more efficient and safe manner to ascertain the various obstacles or barriers to successful and effective implementation of BIM in the management of H&S in an organisation.

Regular on-site safety meetings and training enable global construction companies operating in KSA to have an input from their experts throughout the world who can see the 3D model. It enables the designer to feed information to the contractor throughout the build phase. It removes the need for paper 2D drawings to be carried around the construction site. The model can be electronically transmitted to a hand-held device that several people can access at the same time.

It can be electronically transmitted to screens placed at important point on the site. Another advantage of this is the facilitation of communication between contractors and subcontractors, and between contractors and their workforce. This presentation of information in the most accessible manner, in visual terms, can scale the language barrier which, as was seen in the literature review is one of the greatest challenges to safety where a migrant labour force is employed. It can enable a spread of information at induction safety meetings and at regular meetings held by the site safety officer, either for the entire staff or for those who might be involved in a specific task.

Therefore, according to this study, there exists a division between intelligence and knowledge, and it is emphasised that there is a need not merely to exchange product and process information, but also to include a coordination of the opinions, concerns and specific issues present. Knowledge, it could be said, is a qualitative matter. In order to share knowledge, there should ideally be a joint understanding of culture, safety climate, expertise, environment and technology. Therefore, in order to use BIM technology to its fullest extent, there has to be some experiential input, perhaps over time, no matter how short. BIM technology may be able to be used more innovatively and usefully when it becomes more widespread. The understanding of safety aided by design technology may not be fully realised until there has been some diverse and multicultural experience of what it can offer, when fully understood and when that understanding can be shared. However, until there is widespread education relating to how BIM works and how it can provide a visual, immediate and sequenced insight into how a building can be perceived and projected, and how those who work on it can be protected, the unique safety features available holistically through BIM may not be recognised by contractors operating on sites in KSA.

4.8 Legislative Codes and Standards

Cotton et al. (2005) conclude their paper on labour standards on construction sites in developing countries by noting that "more regulation is not the urgent issue; incorporating existing legislation into construction contracts and making clauses operational is a priority" (p. 5).

This view, that contracts should include existing legislation on H&S so as to make contractual agreements dependent on compliance, was foregrounded by several interviewees in that study, and sanctions or bonuses were also mentioned. In 2014, Dubai made it a contractual issue that new builds must use BIM to secure national building approval. The fact here is that there are existing regulations in KSA, but contractors largely ignore them. “Labour law” includes additions in the last year to cover most of the concerns raised in this study about H&S of construction site workers. They include the mandatory wearing of safety equipment, safety belts for those who work at heights of six feet and over, and having a paramedic on site for sites employing more than 50 workers. Additionally, a new regulation was created: ‘*it is generally prohibited to let a worker work outdoors between the hours of 12 pm to 3 pm from 15 July to 15 September of each year*’. However, there are some doubts as to whether these laws will be obeyed.

In addition to those regulations and the legislation passed by the government, there are other forms of regulation that are or should be on site. According to the literature review, these are very frequently ignored. They include the collection of incident reports, on-site training, the services of a site manager and notifications of accidents. As has already been mentioned, the UK intends to incorporate building regulations into BIM, so that architects can see whether the planned building is compliant with these. That appears to be a very positive step, but where building regulations are unknown or ignored, and where there is insufficient monitoring of H&S compliance, the best solution may be that contracts should be signed only when H&S matters are fully incorporated into the plan of the proposed works. However, there are other ways in which BIM could assist H&S practices to establish themselves on the construction sites of KSA. These could be proactive rather than reactive. This is certainly the first and most important item for the framework.

4.9 Role of BIM in H&S Outcomes

ICT has been adopted in the developed world to assist in better communication and provide better cooperation between individuals and businesses. The manner in which building ventures work is that they inevitably comprise a large number and range of employees and interested parties, who share information to lower the chances of accidents and injuries and to encourage better choices being made with fuller, more detailed data. Despite this, there has not been a particularly large improvement in H&S within the construction sector, even with the advance and advantages of computerisation (Aguilar & Hewage, 2013). Therefore, pragmatic and useful technology is needed at least partly to begin rectifying this situation.

Over the last few years, there have also been rapid advances in mobile computing. This type of computing can be described as that which enables the owner to use their device in any location, or even whilst travelling between different locations and without the need, necessarily, to be connected to a power supply or have any cables with them.

BIM offers possibilities for improved H&S outcomes: visual presentation cuts across the barriers of language, but video screens in the workplace or hand-held technology may produce the safety message in a visual, non-verbal and, therefore, non-threatening way (see Figure 4-3). New technology can cross the barrier between management and worker and offer instant translation. Workers can also perhaps use translation technology to remain in touch with each other. It is surprising that KSA has not yet fully accepted the opportunities that technology can offer to the current workforce and play to the strengths of a multicultural workforce. Chiu and Russell (2011) argue that the adoption of visualisation tools can both enhance communication between the employees and the choices they make, improve their understanding of the information provided to them and produces more thorough and detailed data, a better ability to understand and convey the data, reduces the chance of misunderstandings, conveys the project's drift as regards time and budget and examines the standard of the project's timescale.

BIM allows safety measures to be incorporated in the design phase of construction project: over the years, the building engineering and construction industry has gradually become more complex and wide-ranging; therefore, BIM as a vital resource that helps to ensure safety through the continuous and robust supervising of data and project management and is crucially important in the entire overseeing of all stages of a construction venture, whether this is the initial re-direct or the very last phase (Skibriewski & Ghosh, 2009).

Therefore, the early development stages of a build can offer the best chances to eradicate, or at least greatly minimise, dangers and risks before they have a chance to arise on an actual construction site. Prior study in this area suggests that there have been insufficient methods or mechanisms to help developers confront this problem (Ku et al., 2010). Skibriewski and Ghosh (2009) point out that another challenge posed to the construction sector is that it does not have a rigid, pre-set flow of production and, therefore, may lack the ability to test the product, the building, before constructing it.

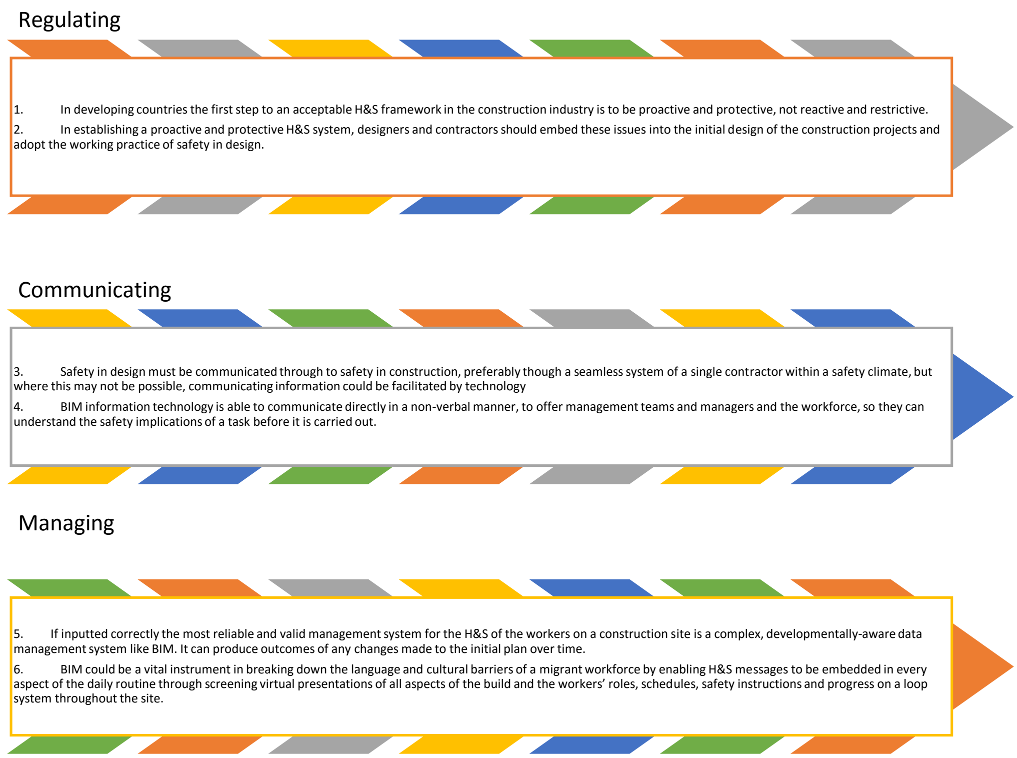

Figure 4-3: BIM and H&S in the Construction Industry

Kiviniemi et al. (2011) report that 44% of deaths on construction sites worldwide are related to design issues and could have been prevented in the initial design. Informed by these statistics, designers and architects who work with BIM have adopted the strategy of identifying probable hazards and resolving H&S problems at the design stage. It has been said that in the past, and in some cases in the present also, safety has been considered as separate from construction planning. Currently, those who adopt BIM methodology are operating from the standpoint that design should be capable of protecting its constructors and preventing accidents. This view and strategy has been named "safety in design". One of the major advantages of BIM is that the design can adapt seamlessly to design faults that have the potential to create hazards.

However, there are two practical barriers to the adoption of safety by design in a country where the DBB tradition operates, as it does in KSA. This often has the effect of separating the design stage from the building phase. This means that the construction is already planned before a contractor bids for the build itself. This effectively is a barrier to safety by design and the use of BIM because the use of the technology must continue throughout the build. Additional considerations include the ability of BIM to enter 4D (scheduling) and 5D (ongoing costs). It makes little sense for the 3D, 4D and 5D design elements not to be available as a tool for deciding on the successful bid. It is clear, however, that the DBB choice of awarding the project to the lowest bidder and the false division between design and build is not always applied in KSA. If it had been awarded to the AECOM company, they would have had to separate their own design and contracting services with the possibility that their BIM adoption in design with its built-in safety features might have been disregarded in the build stage. In this instance, one company took on both roles.

Another barrier to the use of safety by design is the division of responsibility in the DBB model. When this is used and strongly adhered to, responsibility for all safety aspects of the build itself lies entirely with the contractor. This would mean that the design team is not fully committed to safety, as it is possibly not something they need to concern themselves with at that early stage before bids have been accepted. Therefore, a seamless system of procurement that uses BIM throughout its coordinated design and construction stages would enable safety by design to operate. The division of labour and responsibility appears to threaten the basic H&S needs of those working on construction sites in KSA. It is very important for designers and builders to communicate if the highest standards of safety and wellbeing are to become a reachable goal. And this is only one of a number of issues that involve barriers to safety being created through failures in communication.

BIM provides opportunities for 3D/4D/5D visualisation/simulation: 3D and 4D digital imagery for H&S induction presentations is a step towards bridging the communication gap caused by verbal barriers. The 3D demonstrations help with a clear explanation of each phase of building ventures, especially when dealing with KSA's migrant workforce. Verbal direction and multiple interpreters can be substituted by digitally created visualisation in site inductions. From a H&S perspective, such as presenting the upcoming task to the employees, this could be outlining the safety rules and specifications for a particular stage or element of the project and an explanation of potential risks and dangers. Aguilar and Hewage (2013), for example, argue that 4D presentation offers a more detailed and thorough understanding of such a project than conventional 2D graphics and timescales. Jongeling and Olofsson (2007) concur, noting that 4D imaging offers its clients a simple and comprehensible visualisation of the project's anticipated timescale, as well as assisting in the communication between the many stockholders of the construction at hand. Thus, 4D BIM can also be adopted as a method to see the dangers or risks that may arise during the work.

These can be viewed in 3D as information is added to the on-going visualisation. Rather than using 2D paper designs and outlines that may be difficult to read and certainly difficult to use in communicating a hazard, the creation of a 3D model makes the project visible in all its aspects. Therefore, it can be seen quickly where scaffolding, safety rails, work space where heavy machinery is operating and where safety equipment must be used. Interestingly and usefully, BIM does not incorporate all building safety codes and regulations from all nations. Instead, these codes are input manually according to the specific H&S regulation operating in that country. This, in short, means that possible H&S problems arising on building sites that are environmentally or culturally specific and covered by building codes or regulations for that country can be added to the design characteristics that should be considered. For instance, the high temperatures in the summer months in KSA that impact on worker comfort and work efficiency are now embedded in KSA H&S regulations, and from there can be entered as input to BIM. Kiviniemi et al. (2011) have written about the holistic nature of BIM, in that rather than a drawing, this system is basically a simulation, in which everything necessary can be incorporated as the building presents all its features simultaneously.

BIM improvise opportunities for strong and clear communication links between all stakeholders: at its worst, communicating can be top down in a hierarchical and dogmatic manner, or bottom up in a disempowered and disengaged manner. At its best, it is a cooperative interchange of ideas and experience that most resembles a transaction. But it need not involve one-to-one and person-to-person interchanges. Communication can be a process in itself, such as the medium of technology and the kinds of information this can enable. On a macro level, it can also be an exchange of vital information between one organisation and another or between one section of a sequence and the next, within a system. It can exist through words, pictures, sounds and touch, amongst other means and methods. However, without its full employment, no organisation of any kind could exist or make progress.

A computerised safety mechanism was formulated by Zhang et al. (2013), designed with the capability of notifying building engineers, supervisors and the managerial team of all the specifics of the H&S aspects required; and, importantly, how and why these are required, in order to reduce the risk of falling incidents, prior to the construction work commencing. Benjaoran and Bhokha (2010) problem out that could be the limited, if developing, use of advanced information technology in KSA, as referenced in the literature review and evidenced in the results. The use of personal technology and a technophile culture assists with communication in a very basic way, limiting the need for excessive verbal material. The use of emoticons, of instagrams, “selfies”, txtspk and memes enables a cultural understanding that communication can be non-verbal or shorthand and that information can be shared instantly with thousands of others. It is this constant use of alternatives to words that can make for an easier and rapid exchange of information between one part of a building project and another, or one member of a construction team and another. Traditional understandings of what is understood by information sharing can be overtaken by the ease and more focused use of technology, like BIM.

BIM improves the management of data: one of the most important issues in H&S is to learn about what management means. Essentially, it involves looking at data of whatever kind, placing them in appropriate locations and learning from what they then convey. It is one of the most important features of management that if data are entered and saved correctly, then accurate results will be provided. The same is true of any research study and of any decision-making process. The outcomes are enabled by two factors. One is the clarity of the data collection and input; the second is the ability of a software program or storage space to manage that and provide a result when asked for it. This is the most important feature of BIM as a technological development. If the data are correctly collected and uploaded, they can be managed by BIM, and the results obtained will be the most reliable. As with all data-dependent programs, depending on the accuracy of the input, the outcome will be accurate.

In the past, and even recently, the ability of a simulation program to weigh all input, coordinate it with other input and give a reliable result was limited. With BIM, the data are combined within the program and will produce not only a result but also a visualisation of the construction, depending on the data provided. It is clear, therefore, that the collection and input for BIM must use all tried and tested methods currently at the disposal of researchers in fields including architecture, surveying, designing, construction, engineering, material management, accountancy, human resources and H&S. If this is done well, what will be produced will be something that can be relied upon; therefore, the BIM simulation itself becomes the project management process. That applies to materials, process and construction itself, the non-human elements of management. However, if human needs are input into the data, then results will manage the best means of ensuring their efficacy and safety. Furthering reliability is the fact that this is a program that allows changes over time and that visualisation can continually update end results of changes and developments.

4.10 Identifying Gaps in the Literature

This research study is exploratory. Its objective is to discover more about the understanding of H&S issues in the construction industry workforce in KSA and to examine the nature of the challenges presented to it. In a review of literature on this subject, it has examined what has been studied and identified to date and any conclusions that may have been arrived at by researchers. Three research questions have arisen from the first part of the literature review, that part investigating current practices in the industry and the views of those engaged in the construction industry in KSA as far as H&S are concerned.

Crucially the study will take account of the contributions to the framework that could be made by BIM technology. It is important to recognise that although BIM is a new tool within the construction industry, it can facilitate the and enable solutions to many of the problems that have been seen to present themselves both in Saudi Arabia and in many other developing countries that are attempting to build an infrastructure for present and future growth

4.11 Finding

In the literature review, H&S regulation, requirements and recommendations in developed nations usually contain; H&S guidelines, Training frameworks, Practice codes, Regular site inspections, Safety equipment and Information and guidance provided by a central trade body. Reviews of system management safety (SMS) audits should be carried out at least once a year to identify each of the critical elements of the SMS and decide whether matters are going well and if any changes need introducing. The major aim of the research was to provide a method to be utilised by inspectors within the construction industry in assessing H&S performance/improvement over a period of time within a specific sector.

The findings on H&S is viewed within the literature review as a top-down process. Thus, it is essential for action to be taken at the administrative level to improve H&S outcomes. If managers can understand H&S needs and implement a procedure to put best practice into effect, it is likely to succeed. It is observed that co-workers' safety norms have a significant influence on the at-risk behavior of an individual. It was also found out that the fellow workers' perception on health and safety affects an individual's level of compliance towards safety.

The roles and responsibilities of stakeholders (e.g. construction manager) cover a wide range of areas in the construction process. Management should ensure that sufficient resource is allocated for safety activities and that regular safety meetings and training are in place. Influence of the Supervisors is the immediate hierarchical position for the worker, play a pivotal role in company health and safety practices. Majority of safety procedures, monitoring means which come from the senior management are implemented by supervisors. In a study conducted on employee attitudes towards safety, Cheyne, et al. (2002) found the physical working environment as a key factor contributing to safety activities of organizations.

Role of BIM in H&S Results It is seen that in the past, and even recently, the ability of a simulation program to weigh all input, coordinate it with other input and give a reliable result was limited. With BIM, the data are combined within the program and will produce not only aresult but also a visualisation of the construction, depending on the data provided. It is clear, therefore, that the collection and input for BIM must use all tried and tested methods currently at the disposal of researchers in fields including architecture, surveying, designing, construction, engineering, material management, accountancy, human resources and H&S.

ICT has been adopted in the developed world to assist in better communication and provide better cooperation between individuals and businesses. The manner in which building ventures work is that they inevitably comprise a large number and range of employees and interested parties, who share information to lower the chances of accidents and injuries and to encourage better choices being made with fuller, more detailed data. However, there are two practical barriers to the adoption of safety by design in a country where the DBB tradition operates, as it does in KSA. This often has the effect of separating the design stage from the building phase. This means that the construction is already planned before a contractor bids for the build itself. Additional considerations include the ability of BIM to enter 4D (scheduling) and 5D (ongoing costs). It makes little sense for the 3D, 4D and 5D design elements not to be available as a tool for deciding on the successful bid.

BIM offers possibilities for improved H&S outcomes: visual presentation cuts across the barriers of language, but video screens in the workplace or hand-held technology may produce the safety message in a visual, non-verbal and, therefore, non-threatening way. New technology can cross the barrier between management and worker and offer instant translation. Workers can also perhaps use translation technology to remain in touch with each other.

4.12 Summary

This chapter has examined the literature addressing the use and possibilities of BIM in the construction industry in developed countries, as well as highlighting the relationship between BIM and H&S outcomes. To demonstrate the value of BIM in H&S, emphasis has been placed on how and why BIM can and should be used for visualisation in the design phase, as well as in construction. In particular, Chapter 3 puts forward three ways in which BIM stands to enhance H&S outcomes in KSA construction industry, focusing on the development of hazard assessments and 3D/4D imagery.

To address this gap, Chapter 5 outlines the research design, including the methodology for data collection and analysis. It discusses paradigms and theoretical approaches that governed the study considerations. Moreover, it presents the alignment between the research problem, the research questions, the data collection and analysis processes and how these relate back to the stated aim.

Chapter 5. Research Methodology

5.1 Introduction

The methodology in this chapter has been adopted in order to achieve the aim and the objectives of this research. This chapter starts by clarifying the research design used in this study. This is followed by a discussion of the research philosophy, explaining various methods and means to achieve the objectives and aims of the research. Finally, chosen subtitle methods and techniques used to achieve the aim and the objectives of this research are presented.

5.2 Research Design

Mingers (2001) defines methodology as a set of guiding rules or activities that help to generate accurate research findings. Fellows and Liu (2004) explain that it consists of methods and principles that generate rational thinking. Saunders et al. (2003) use the analogy of a six-layered onion (see Figure 5-1) to explain the research process. They highlight the importance of ascertaining the philosophy of the research work; planning the research methods; following a specific method to carry on the research work; maintaining a timetable and choosing the best methods to collect and analyse data.

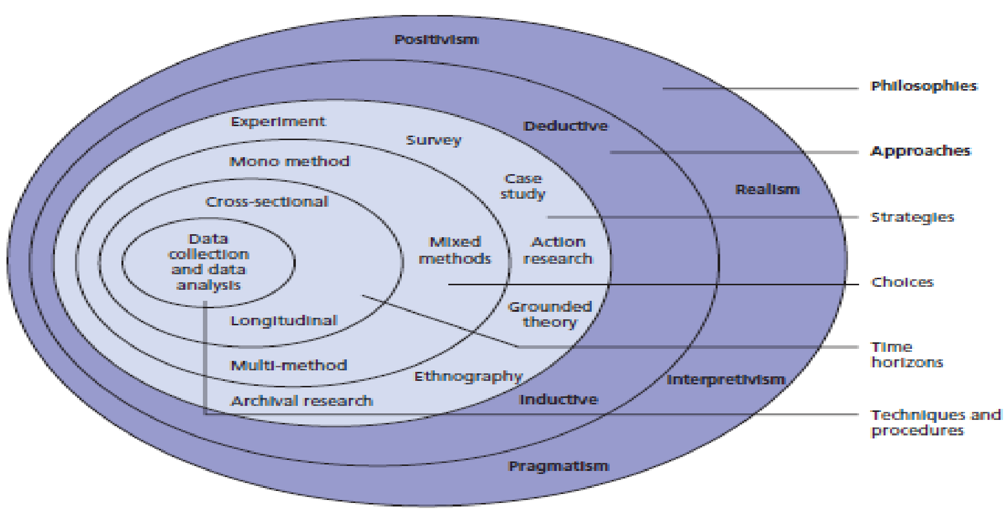

Figure 5-1:Research Process Onion

(Source: Saunders et al., 2009)

The most important task in the first layer of the research onion is to understand one's philosophical stance in relation to the research question(s) posed, which generally dictates a location within a paradigm. Remenyi and Williams (1998) highlight that researchers' ideas about the nature of the world and what constitutes knowledge have been an important factor in the development of scientific methods of research. Easterby-Smith et al. (2012) identify two "poles" of the philosophical spectrum (positivism and phenomenology) that can be usefully employed to reflect on one's research approach. However, the majority of researchers do not use "phenomenology" in this way but class it as a form of interpretivism, the paradigm most usually considered as the opposing paradigm, as Saunders et al. (2009) do in the above graphic. Choosing or understanding one's philosophical position in answering the research questions requires very careful consideration, as this has important implications for structuring data collection and analysing research data: "It is the researcher's understandings and associated decisions in relation to these outer layers that provide the context and boundaries within which data collection techniques and analysis procedures will be selected" (Saunders et al., 2009).

Consistent with the position of Saunders et al. (2012), Easterby-Smith et al. (2012) also give three important reasons why the researcher should understand their philosophical position, Firstly, they argue that the philosophical position helps to explain the methods of the research; secondly, they maintain that the researcher gains knowledge of the designs that will work the best in the chosen paradigm; and thirdly, they point out that, through considering their philosophical position, the researcher can consider designs they may not have been previously familiar with.

Saunders et al. (2012) illustrate this relationship as follows:

> A researcher who is concerned with observable phenomena, such as the resources needed in a manufacturing process, is likely to have a very different view on the way research should be conducted from one concerned with understanding the subjective meanings of the feelings and attitudes of the workers in that same manufacturing process.

Although Saunders et al. (2009) do not specifically include ontology, epistemology and axiology in the onion model, they are implicit in each of the philosophies which they do include (positivism, interpretivism, realism and pragmatism). This is the case since each of these philosophies (with the possible exception of pragmatism which posits a choice of research methods driven by the research question rather than allegiance to a particular paradigm) includes, to a greater or lesser extent, beliefs about how knowledge is acquired about the world, the nature of reality and value judgments. Saunders et al. (2012, pp. 109-110) considers that ontology, epistemology and axiology are, in fact, dimensions within which competing philosophies can be evaluated, compared or understood.

Bryman and Bell (2007) support the argument that the epistemological and the ontological positions adopted by the researcher are of great importance, as they affect the selection of the research methodologies and also structure the interpretation of the data which the research generates (see Table 5-1).

Table 5-1:Assumptions of research philosophy (Sexton, 2003)

Epistemology (the "how?")	General set of assumptions about knowledge about the world is acquired and accepted
Ontology (the "what?")	Assumptions made about the nature of reality
Axiology (the "why?")	Assumptions about the nature of values and the foundation of value judgments

(Source: Sexton, 2003)

5.2.1 Ontology

Ontological assumptions can be dived into nomothetic (realism) and ideographic (idealism), as argued by Gill and Johnson (2010) and shown in Table 5-2. Sexton (2003) defines idealism as an unknowable reality perceived in different ways by individuals and realism as a commonly experienced external reality with a predetermined nature and structure. According to Burrel and Morgan (1979, as quoted by Gill & Johnson, 2010), nomothetic (realist) methodologies place an emphasis on the importance of research using rigorous systematic protocols and deductive techniques that focus on testing hypotheses. In contrast, ideographic (idealism) methodologies emphasise analysis of subjective accounts that allow the researcher to get inside situations in the everyday flow of life without disrupting them (Burrel & Morgan, 1979, as quoted by Gill & Johnson, 2010). Accordingly, idealism might be identified as the most appropriate ontological philosophy for this study because the H&S management practices in the Saudi construction projects are not known. In employing inductive reasoning to use emerging data to develop a framework, this research is ideographic in that it seeks to understand the phenomenon of BIM in H&S without the controls or limitations of testing existing theories.

Table 5-2: Comparison of nomothetic (realism) and ideographic (idealism) methodologies .

	Nomothetic	Ideographic
1	Deductive testing of theory	Inductive development of theory
2	Explanation via analysis of causal relationships and explanation by covering-laws	Access to subjective meaning systems and explanation of behaviour through understanding
3	Generation and use of quantitative data	Generation and use of qualitative data
4	Use of various controls, physical or statistical, so as to allow the rigorous testing of hypotheses	Commitment to research in everyday settings, whilst minimising the disruption caused by the research to those being investigated, so as to preserve the natural context in which their behaviour arises
5	Highly structured research methodologies to ensure replicability of points 1-4 above	Minimise structure to ensure 2-4 above

(Source: Gill & Johnson, 2002)

5.2.2 Epistemology

Epistemological assumptions can be divided into two categories – those corresponding to the philosophy of positivism and those corresponding to the philosophy of social constructionism (interpretivism), as Easterby-Smith et al. (2012) indicate (Table 5-3). In positivist philosophy, there is a general belief that the world conforms to fixed laws. Such approaches have traditionally been popular amongst natural and physical scientists. Positivist researchers may argue that "the world exists externally and that its properties should be measured through objective measures rather than being inferred subjectively through sensation, reflection or intuition. They use the deductive approach for the research" (Easterby-Smith et al., 2012). This study employs assumptions of social constructionism in that it is collecting data on the phenomenon to advance the situation, accounting for stakeholder perspectives for the purpose of theoretical abstraction. In other words, while BIM usage in H&S in KSA construction industry is to be studied, the purpose of understanding it is to gain the ability to improve it.

Table 5-3:Contrasting implications of positivism and social constructionism.

Assumptions about	Positivism	Social Constructionism
The observer	Must be independent	Is part of what is being observed
Human interest	Should be irrelevant	Are the main drivers of the science
Explanations	Must demonstrate causality	Aim to increase general understanding of the situation
Research progress through	Hypotheses and deduction	Gathering rich data from which ideas are induced
Concepts	Need to be operationalised, so that they can be measured	Should incorporate stakeholder perspectives
Units of analysis	Should be reduced to the simplest terms	May include the complexity of "whole" situation
Generalisation through	Statistical probability	Theoretical abstraction
Sampling requires	Large numbers selected randomly	Small numbers of cases chosen for specific reasons

(Source: Easterby-Smith et al., 2012)

Interpretivism, by contrast, involves an epistemology that "is directed at understanding phenomena from an individual's perspective, investigating interaction among individuals as well as the historical and cultural contexts which people inhabit" (Creswell, 2009). Moreover, "it is necessary to explore the subjective meanings motivating the actions of social actors in order for the researcher to be able to understand these actions" (Saunders et al., 2009, p. 111). They argue that an interpretivist paradigm may often be highly appropriate in business and management research, particularly in such fields as organisational behaviour, marketing and human resource management.

5.2.3 Axiology

Saunders et al. (2009) consider that that how the researcher deals with value judgments is the third aspect of the research philosophy (see Figure 5-2). Axiology can be seen as having two poles, namely "value free" and "value laden". The choice of the subject and method of study is different in each of these axiological positions. In "value free" studies, the selection of topic, as well as the method of study, depends on the aim criteria; but in "value laden" research, what to study depends on experiences and beliefs of humans (Easterby-Smith et al., 2012) (Fig. 5-3).

This research is value laden, as it focuses on the current state of a phenomenon, H&S in KSA construction industry, for the purpose of improving outcomes.

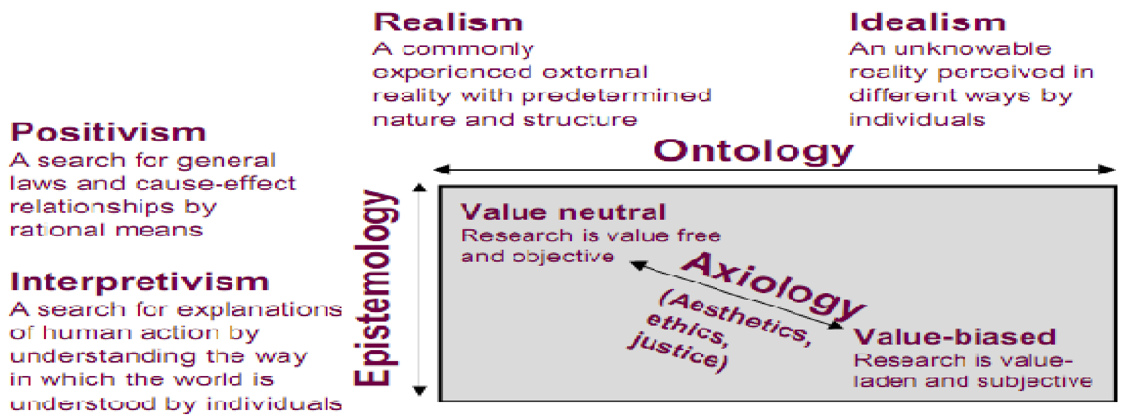

Figure 5-2: Research philosophy

(Source: Sexton, 2003)

5.3 Research Approach

In the second level of onion research, the essential choice to be made is between deductive and the inductive approaches. The deductive method centres on theory testing, particularly through testing hypotheses using some form of quantitative procedure (e.g. inferential statistics), while the inductive approach aims to build up new concepts and develop new theories from the data collected (Gabriel, 2013). Deduction is usually associated with quantitative research work, whereas inductive research is associated mostly with qualitative research; but these are associations rather than rules, so that either deduction or induction can be part of qualitative or quantitative research (Gabriel, 2013).

This research study, although using a mixed method combination of a survey and semi-structured interviews, utilises an inductive approach. Inductive reasoning is appropriate for this study, as data collection focuses on specific observation, from which broader generalisations are drawn to develop the framework. While deductive research is aimed at testing theory, inductive research is used to generate theory from emerging data. In the context of this study, the theory takes the form of a new framework. Research questions are being addressed in this study, in order to build up explanation and theory. Specific hypotheses are not tested.

5.3.1 Methodological Choices

This section refers to the selection of appropriate research methods adopted to collect the data. Saunders et al. (2012) present this in diagrammatic form (Figure 5-3), classifying the research choices into two sections: mono method (using a single data collection technique and corresponding analytical procedures) and multiple methods (using more than one data collection technique and corresponding analytical procedures to answer the research question).

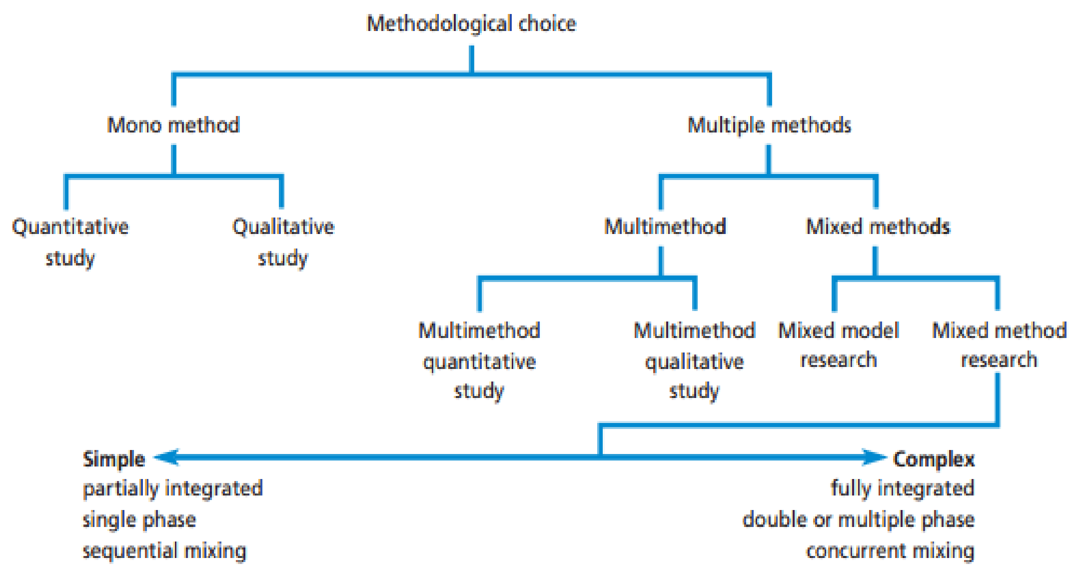

Figure 5-3: Research choices

(Source: Saunders et al., 2012)

Mixed methods are chosen to answer these research questions using the strengths of quantitative and qualitative research. Mixed methods are appropriate for this study, as they allow the researcher to address the phenomenon from more than one relevant angle for the purposes of collecting ample data and developing a robust framework. Quantitative research may be employed to plug the gaps in a qualitative study that arise because, for example, the researcher cannot be in more than one place at any one time. Alternatively, it may be that not all issues are amenable solely to a quantitative investigation or solely to a qualitative one" (Saunders et al., 2012). Moreover, Tashakkori and Teddlie (2003) argue that multiple methods are useful if they provide better opportunities for answers to research questions and where they allow better evaluations of the extent to which research findings can be trusted and inferences made from them.

5.3.2 Mixed/Multi-method Research

The term 'multi-method' refers to studies where data collection techniques are combined within a study but the two are not integrated with each other, i.e. quantitative data gathered are analysed within a quantitative framework only and qualitative data is analysed within a qualitative framework only (Tashakkori & Teddlie, 2003). Many recent research studies, the latter claim, are adopting different aspects of both the qualitative and quantitative systems. It is suggested that several researchers have benefited considerably from these strategies that connect usefully to each of the systems and, by doing so, have been able to shed light on drawbacks that may be revealed in one or other of the approaches (Mingers, 1997; Morgan, 2006). Saunders et al. (2009) indicate that mixed method research uses quantitative and qualitative data collection techniques and analysis procedures either at the same time or sequentially, but are not necessarily combined. Qualitative data are analysed qualitatively and quantitative data are analysed quantitatively. Differences and strengths and weaknesses between them are presented in Tables 5-3 and 5-4, respectively.

Strauss and Corbin (1990), the researchers who developed grounded theory, offer the opinion that any research that is based on a qualitative method is more appropriate than that which involves quantification or statistical methods. They further explain that qualitative research offers results that are simple and general in nature, whereas qualitative researchers are in search of understanding and the relation of this situation to others. However, the quantitative method of research is more than generating numbers and statistics. It usually tests a pre-chosen hypothesis by use of quantitative concepts, including analysis and evaluation of significance. In quantitative research, experiments may sometimes be used (Strauss & Corbin, 1990). However, it is not necessary for a study to be restricted by the two aforesaid methods. According to research philosophy, both the qualitative and quantitative approaches can be used in a mixed methodology, which Patton (1990) feels is the most appropriate method. In other words, a research study can adopt any of the paradigms and employ either qualitative or quantitative methods for data collection and analysis, or a combination of the two, according to its overall requirements and the information needed to answer the research question(s). However, there are some rules that should be followed in mixed methodology. The study can be complete only if there is scope for using both methods for analysis and evaluation of the data.

Table 5-4:Differences between quantitative and qualitative research

	Quantitative	Qualitative
Role	Fact-finding based on evidence or records	Attitude measurement based on opinions, views and perceptions measurement
Relationship between researcher and subject	Distant	Close
Scope of findings	Nomothetic	Idiographic
Relationship between theory/concepts and research	Testing/confirmation	Emergent/development
Nature of data	Hard and reliable	Rich and deep

(Source: Bryman, 1998, as quoted by Naoum et al. 2007)

This study adopts a mixed methods approach, which in terms of Saunders et al. (2009) taxonomy is mixed methods research (see also Table 5-5):

> "Mixed method research uses quantitative and qualitative data collection techniques and analysis procedures either at the same time (parallel) or one after the other (sequential) but does not combine them. This means that, although mixed method research uses both quantitative and qualitative worldviews at the research methods stage, quantitative data are analysed quantitatively and qualitative data are analysed qualitatively. In addition, often either quantitative or qualitative techniques and procedures predominate" (pp. 152-3).

5.3.3 Quantitative Data Collection and Analysis

The philosophical origin of quantitative research methods is physical science; hence, it has to depend on the objectivists' presumptions and insight about society as a whole. Research studies utilising these methods are carried out through dispassionate systems of gathering data and analysing it quantitatively by means of numbers. It employs "empiricist" or "positivist" paradigms; it adopts the stance that there is a sole existing reality in the world, which is enforced by natural laws and is, therefore, unquestionable and is not dependent on human explanations

(Creswell, 2013). Moreover, quantitative research is dependent on two study methods, namely experimentation and research on surveys (Bashir, 2013; Creswell, 2013).

Table 5-5: Strengths and weaknesses of quantitative and qualitative research.

	Quantitative	**Qualitative**
Strengths	Can provide wide coverage of a range of situations. Can be fast and economical. Where statistics are aggregated from large samples, may be of considerable relevance to policy decisions.	Data gathering methods seen as more natural rather than artificial. Ability to look at change process over time. Ability to understand people's meaning. Ability to adjust to new issues and ideas as they emerge. Contributes to theory generation.
Weaknesses	The methods used tend to be rather inflexible and artificial. They are not very effective in understanding processes or the significance that people attach to actions. They are not very helpful in generating theories.	Data collection can be tedious and require more resources. Analysis and interpretation of data may be more difficult. Harder to control the pace, progress and end-points of research process. Policy-makers may give low credibility to results from qualitative approach.

(Source: Easterby-Smith et al., 2012)

A survey within a positivist paradigm is a method of collecting data systematically from a chosen number of individuals. It involves distributing questionnaires to those participating in the study or conducting generally closed-question online, face-to-face, email, postal or telephone questionnaires to participants sampled from the population of interest; these may be self-administered or interviewer-administered. Each survey mode has particular advantages and disadvantages (Fowler, 2009).

5.3.4 Qualitative Data Collection and Analysis

Qualitative research methods are based on the importance of the subjective perception of the real world and acknowledging how it is idiosyncratically experienced. Unlike the employment of quantitative methods, most qualitative methods are used within an interpretivist paradigm in which there are no instrumental measures. Instead, the researcher is the instrument through which data is collected and analysed. It is a subjective rather than an objective stance, and while this is regarded by its critics as being unreliable for this reason, those conducting this research are encouraged to undertake a practice of reflexivity and constant self-examination that can be one of the strengths of its paradigm.

Social constructivism is a form of interpretivism. Its guiding principle is that truth is not “out there” and realistic, but is constantly and fluidly socially constructed by populations and groups. According to Creswell (2013), when the qualitative method is the means of data gathering and analysis, there are chances of meeting with different realities; these are the concepts and ideas of various individuals belonging to different cultural, political or socio-economic groups who have expressed their beliefs and understandings in different environmental conditions. Hence, the researcher takes note of all information gathered and different views, then reports these truths but does not seek to decide directly which idea is the “truth” or the nearest to reality (Bashir, 2013).

Practically, qualitative research is dependent on two techniques – field research that involves fieldwork and the research system that is non-reactive. In the first method, direct contact with persons is involved and first-hand knowledge is collected; while the latter uses observational instruments that are unobtrusive or study materials, archived accounts and official statistics related to previous social life (Brewer & Hunter, 2006). In this type of study, the researcher does not seek to test hypotheses but, rather, to utilise questions to guide them to reach the primary goals and complete the tasks required.

In this study, it is clear that there should be a qualitative aspect to enable the researcher to answer the research questions in a reliable and rounded manner. This can perhaps produce results that are transferable rather than replicable, and this type of data collation and analysis can add depth and understanding.

5.4 Research Strategy and Approach

According to Naoum et al. (2007), research strategy is defined as the way in which the research objectives can be most comfortably questioned. This is the fourth level of the research onion, which is one of the most important stages in this study. Choosing an appropriate theoretical approach is difficult because it has to provide direction and act as vehicle when attempting to address the research questions and objectives within the time available, as well as in the chosen paradigm. In order to avoid confusion and obtain clarity about the methodology and how it can meet the research questions, this researcher adopted a survey theoretical approach (see Section 5.4.1) because this approach, above all others, provides a fit with the research objectives and questions.

A mixed methods strategy has been chosen for this research study. The utility of using both qualitative and quantitative methods simultaneously is that information is collected and analysed in two different but parallel ways, whereby information generated by one method can be seen to inform the other collection and analysis method (Creswell, 2013) (see Table 5-6).

Table 5-6: Reasons for using mixed method design

Reason	**Explanation**
Triangulation	Use of two or more independent sources of data collection methods to corroborate research findings within a study
Facilitation	Use of one data collection method or research strategy to aid research using another data collection method or research strategy within a study (e.g. qualitative/quantitative providing hypothesis, aiding measurement, quantitative/qualitative participant or case selection)
Complementarity	Use of two or more research strategies in order that different aspects of an investigation can be dovetailed (e.g. qualitative plus quantitative questionnaire to fill in gaps quantitative plus qualitative questionnaire for issues, interview for meaning)
Generality	Use of independent source of data to contextualise main study or use of quantitative analysis to provide sense of relative importance (e.g. qualitative plus quantitative to set case in broader context; qualitative x quantitative analysis is to provide sense of relative importance)
Aid interpretation	Use of qualitative data to help explain relationships between quantitative variables (e.g. quantitative/qualitative)
Study different aspects	Quantitative to look at macro aspects and qualitative to look at micro aspects
Solving a puzzle	Use of an alternate data collection method when the initial method reveals inexplicable results or insufficient data

(Source: Saunders et al., 2009, p. 154)

5.4.1 The Survey as a Theoretical Approach

Saunders et al. (2009) state that the survey approach when located entirely in the positivist paradigm is usually associated with deductive rather than inductive reasoning and is common in business and management research. It is most frequently used to answer questions to do with "who", "what", "where", "how much" and "how many", rather than "why" and "how", and also concentrates on testing hypotheses.

Fellows and Liu (2008) report that survey approaches of this kind operate mainly on the basis of statistical sampling and only extremely rarely are full population surveys (such as a census) possible, practical or desirable. The advantages and disadvantages of the quantitative elements in surveys are highlighted below (Fellows and Liu ,2008).

Potential advantages of surveys include:

- With an appropriate sample, surveys may aim at representation and provide generalised results
- Surveys can be relatively easy to carry out and need not require any fieldwork or data entry (e.g. if they are self-administered online)
- Surveys may be repeated in the future or in different settings to allow comparisons to be made
- With a good response rate, surveys can provide substantial data relatively quickly

Potential disadvantages of surveys include:

- Data in the form of tables, pie charts and statistics may become the main focus of the research report. This may sometimes be seen as excessively reductionist or abstract and, therefore, there may be a loss of linkage to real human experiences or wider theories and issues
- The data provide static snapshots of points in time rather than a focus on the underlying processes and changes
- The researcher is often not in a position to check first-hand how well the respondent understands the questions. Issues of truthfulness and accuracy are thereby raised

- The survey relies on breadth rather than depth for its validity. This is a crucial issue for small-scale studies
- Sampling error or bias may mean that the findings from the sample do not accurately reflect the population from which it is drawn

Response bias is often a feature of questionnaire participants: "Response bias occurs in survey research when the responses do not actually reflect the views of the sample and the population. For example, the individuals who return a questionnaire may be overly negative or positive " (Creswell, 2005, p. 368). Moreover, participants, being anonymous, can sometimes appear to falsify their response for a variety of reasons, most of them psychological.

Other survey studies using elements of the interpretative paradigm and inductive reasoning attempt to find relationships between the characteristics of the respondents and their reported behaviours and opinions. Marczyk et al. (2005) explain that many survey studies ask large numbers of people questions about their behaviours, attitudes and opinions, although some surveys merely describe what people say they think and do.

5.5 Time Constraints

Saunders et al. (2009) opine that the cross-sectional approach is a snapshot, while the longitudinal approach would be shown, for example, in a diary. This study is cross-sectional, as the data are collected once, relating to a particular phenomenon at a given point in time from the viewpoint of a number of participants. As the above authors acknowledge, most research studies undertaken for academic courses are necessarily time-constrained and, in any event, it is unlikely that firms would have consented to participate in a longitudinal study.

5.6 Qualitative Data Collection

The data collection methods in this study includes face-to-face interviews with several stakeholders, including construction managers and site supervisors, to identify the current status of management of and obstacles to H&S issues in KSA construction projects. As well as primary data, numerous secondary data were gathered from the literature review, including journal articles and conference reports, government reports, statistical data and several other internet resources and websites for relevant governmental agencies.

5.6.1 Interview Method

The interview method involves questioning or discussing issues with people (Saunders et al. 2009)). Different techniques are used for interviews, like telephone, Skype or direct interviews and focus meetings. The latter method is employed when direct interaction is necessary, so that the situation can be handled in more detail. De Vaus (2002) is of the opinion that face-to-face interaction can be carried out singly or as a part of a group. The current study, however, utilises the one-to-one interview system.

Saunders et al. (2009) indicate that in adopting an interpretivist epistemology, the researcher as interviewer will be concerned to understand the meanings that participants ascribe to various phenomena. This method involves collaboration between the researcher and the participant, to gain the necessary information. According to Fellows and Liu (2003), the interview has many advantages. It provides an opportunity for close interaction between the interviewer and the respondent, allowing for high level of control of the interview process (Naoum et al. 2007). There is also a higher chance of obtaining detailed and in-depth information that is of high quality. Other advantages lie in the accuracy of the answers, speed, a high response rate, the flexibility to reframe the questions in order to give the researcher a chance to seek further clarification of the issues and obtain more details (Naoum et al. 2007).

Interviews can be in an unstructured, structured or semi-structured format (Creswell, 2013). The unstructured interview is similar to a conversation directly related to the research, where the interviewee is allowed to develop ideas and follow their sequence of thought, in the style of a sharing of views, thus the use of the word “interview”. In a structured interview, the different interviewees are presented with questions in the same order and virtually the same wording in a tightly controlled format of questions and answers (Marczyk, 2005). It is like a face-to-face administered questionnaire (Denscombe, 2007). However, a semi-structured interview, though the interviewer has a list of issues to be discussed, is flexible in terms of the order in which the questions are answered and allows the respondent to develop ideas and speak widely on them. Saunders et al. (2009) contend that semi-structured interview schedules should have a list of themes and questions to be covered but that the order of questions may also be varied depending on the flow of the conversation, which allows for additional questions that may be needed to explore aspects of the research questions further. A semi-structured design has been adopted in the qualitative data collection for this study.

The semi-structured interview schedule is divided into five sections:

1. Information about the organisation.
2. Understanding the nature and the processes of construction projects.
3. Current H&S practices of the organisation and its challenges.
4. The current experience, skills and culture of site-based staff.
5. The use, if any, of BIM.

5.6.2 Interview Sampling

This sampling strategy explains the processes and methods of choosing suitable elements (people and organisations), as shown in Table 5-7. As can be seen, the total number of interviews was ten, comprising one official from the General Directorate of Civil Defence in KSA, two ministry consultants, three contractors from the ministry and four engineers from international companies. After the semi-structured interviews were designed, they were piloted with three respondents from the target population to ensure that they found it easy to understand the questions. The participants for the semi-structured interviews were recruited from construction contractor companies in KSA. It can be seen from the above table that all interviewees were given a letter of the alphabet to preserve their anonymity and to make the data analysis easier to conduct.

The contractor companies, which are large and complex, mainly use a large number of local and international contractors to carry out their projects. KSA ministries mainly use consultants to supervise and monitor a project and contractors' progress and performance.

According to the Saudi Ministry of Municipal and Rural Affairs (MOMRA, 2014), there are currently 309 engineering companies and 2,785 construction companies registered in the AEC industry. Despite these numbers being substantially lower than those recorded by the Saudi

Council of Engineers SCE, which reports 2,000 registered architecture firms and more than 170,000 registered construction specialists, the MOMRA numbers are considered to be more official than those provided by the SCE as any company accredited through MOMRA is eligible to work in the KSA (MOMRA, 2014). Based on this evidence, this research targeted MOMRA registered firms and construction companies as the target population.

Table 5-7: Interviewee information

Participant	Age	Position	Expertise	Level of education	Area of work	Years of experience
IA	39	Project manager	Construction management	Master	Public sector	12
IB	35	Lecturer	Architecture	PhD	University	5
IC	33	Manager and university lecturer	Architecture and management	PhD	Public sector	6
ID	33	Head of engineering	Engineering	Master	Civil service	10
IE	34	Supervisor of public projects	Engineering	Master	Civil service	8
IF	45	Project manager, international company (Chinese)	Engineering	Bachelor	Private sector	19
IG	44	Civil defence captain	Engineering	Master	Public sector	20
IH	52	Site manager	Engineering	Bachelor	Private sector	25
II	31	Contractor	Architecture	PhD	Public sector	6
IJ	29	Contractor	Architecture management	Master	Public sector	5

5.7 Questionnaire Method

This study adopted a survey as a theoretical framework, to include both the interview and questionnaire methods, with the intention of understanding behaviours, attitudes and opinions of the participants in the construction industry. These need to be answered from different positions, locations and experiences to obtain reliability and transferability. Its aim is to find relationships between the characteristics of the respondents and their reported behaviours and opinions. The proposal of this survey is to classify and gauge the critical issues that might restrict the ability to improve the running of H&S operations in KSA construction industry. Moreover, the survey aims to identify the most important critical factors which have an impact on improving H&S in construction projects. Also, the survey seeks to understand barriers to the adoption of BIM within the H&S in construction industry.

The questionnaire developed for this study is divided into five sections: respondent background; factors related to construction projects; current communication practice in construction projects; construction information needs on site; and challenges that affect the adoption of mobile computing technology (see Figure 5-4).

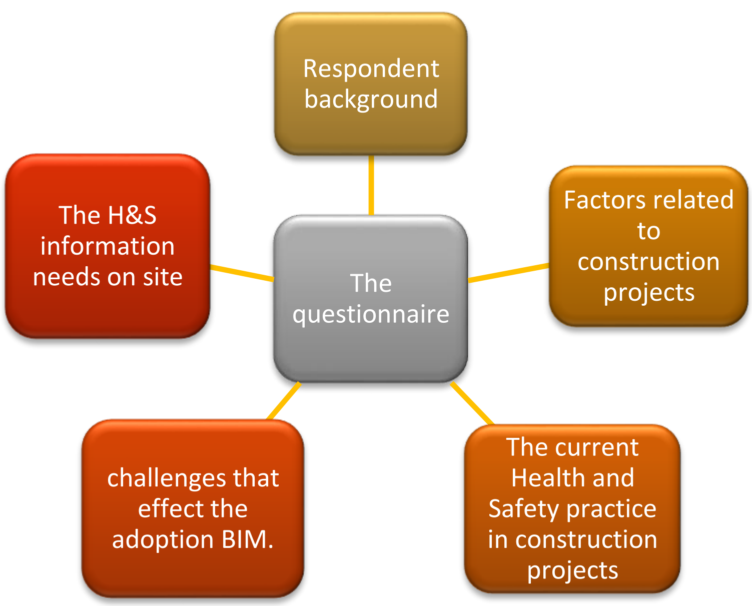

Figure 5-4: Questionnaire sections

5.7.1 Questionnaire Design

The questionnaire was mainly designed with a five-point Likert rating scale “often used to collect opinion data” (Saunders et al., 2009, p. 387), which attempts to measure attitudes and opinions. The response options range from “extremely good” to “not good at all”, from “very important” to “not important at all” and from “most used” to “not used at all”. Possible responses to rating questions should be presented in a straight line rather than in multiple lines or columns, as this is how respondents are most likely to process the data (Dillman, 2011). Moreover, in delivery and collection questionnaires, the five agreement points on the rating scale should allow respondents to tick the middle “neutral” option, as it is less threatening than admitting they do not know. Using this type of scale facilitates the research into determining and assessing the impact of KPI as a method of evaluating improvement in H&S.

5.7.2 Questionnaire Layout

The design of the questionnaire is based on the research objectives and presented in four sections (A-D), which are groups based on the type of information collected in the section. Questions in Section A collect background information on the respondent and their experience in the construction industry, more specifically, size of company and type of construction projects it handles.

Section B collects information on the current H&S issues faced by respondent in the construction industry, including H&S hazards experienced at construction sites. This helps to analyse the current H&S challenges faced by construction companies.

In Section C, the researcher tries to gain an understanding of the current H&S measures undertaken at construction sites. This helps in understanding the extent of its integration into the current safety programmes, as well as the importance of integrated safety programmes and the number of H&S hazards. An organisation with a fully integrated system should have a low number of H&S incidents. Furthermore, this section helps to explore the current precautions taken by the construction industries to avoid H&S hazards. This also enables the researcher to understand the perception of construction site managers regarding the importance of different factors for H&S programmes. This can contribute to analysis of the factors that contribute to

H&S hazards at the construction site. This can offer insights and information relating to research question 2 – existing challenges in the construction H&S and the safety management practices implemented and perceived by Saudi contractors.

In addition, this section provides understanding on the current risk assessment method followed by the organisations=. This helps the researcher to judge whether it has any formal strategy in place to determine risks and hazards on site. This section also collects information on the H&S training provided by the organisations, in order to avoid any H&S hazard at the construction site. This aims to assist understanding the perception of the manager on what is the most effective method for providing training to workers.

Section D is related to BIM and the perception of the respondent regarding its use in reducing H&S risks at the construction site. This helps the researcher to collect data on the current awareness of BIM in the Saudi construction industry and whether, if used, what are main purposes of using BIM other than for H&S. Furthermore, it assists in the exploration of managers' perceptions of BIM regarding whether it can add to existing H&S programmes. This can assist with answering research question 3, on how BIM can enhance improvement of existing H&S programmes on construction sites (see Appendix 2 for a sample of the questionnaire).

5.7.3 Questionnaire Administration and Pilot Study

In piloting the questionnaire, the researcher adopted the advice of Saunders et al. (2009) regarding administering delivery and collection questionnaires:

- Ensure that all questionnaires are sent to participants by email
- Ask all participants to confirm receipt of the email
- Send his comment about the questionnaires
- Ensure that participants place there completed the questionnaires

However, the actual questionnaires were eventually issued online through Survey Monkey and the procedure quoted above was only used in the pilot study.

Pilot study

The pilot study enabled the researcher and the pilot group, made up of colleagues, to discuss and judge the difficulty and relevance of the proposed questions. All questions were thought to be easy to understand and reflected the information sought in the research questions. Furthermore, they gave an opportunity to analyse the results using SPSS software and assist with ease of analysis.

This was found to be satisfactory and the consensus of the group was that, apart from some very minor alterations, the questions were assessed as suitable for this study (see Appendix 2).

5.7.4 Survey Sample

The strategy for selecting people for the survey was a snowball sampling strategy. This requires the support of other people to participate in the recruitment process by approaching potential participants on behalf of the researcher. For this study, it was often a number of professional colleagues who were involved in the recruitment process. Although snowball sampling is a non-probability method, it was suitable for this study, as no comprehensive list of the target population was available to the researcher. In all, the questionnaire was distributed to 300 participants (see Table 5-8).

Table 5-8: Sample size of questionnaires

	Numbers identified (total)	Number contacted (total)	Number contacted from government register	Number contacted from private companies (and number completed in brackets)	Number contacted from public sector companies (and number completed in brackets)	Overall number not responding/refusing to take part	Overall number of completed questionnaires obtained
Invited to named person via email	250	250	28	126 (45)	96	233	51
Via generic web link distributed at these sites	Random On twitter @ Saudi Council of Engineers	Random	Not applicable (generic web link)	Not applicable (generic web link)	Not applicable (generic web link)	Not applicable (generic web link)	129
Overall total		250					180

5.8 Data Analysis

This is a critical phase in any research after primary and secondary data have been collected. This phase contains several key stages which help to obtain a comprehensive understanding of the information requirement, current practices and the surrounding issues, all of which is essential to develop the framework. This step describes how the data collected from the interviews and questionnaires was transformed into useful and reliable information, in order to meet the research objectives and answer the research questions. As this research adopted mixed methods for data collection, there are different techniques in terms of data analysis. Table 5-9 displays the distinctions between quantitative and qualitative data.

Table 5-9: Distinctions between quantitative and qualitative analysis

Quantitative data	Qualitative data
Based on meaning derived from numbers	Based on meanings expressed through words
Collection results in numerical and standardised data	Collection results in non-standardised data requiring classification into categories
Analysis conducted through the use of diagrams and statistics	Analysis conducted through the use of conceptualisation, verbally

(Source: Hair et al., 2007)

In most research studies, data analysis includes a number of steps, such as preparing the data for analysis, analysing it and interpreting it. Preparing data includes checking and entering them into the computer and transforming them. It should also be remembered that data analysis is not a direct route to interpretation. First, some way must be found of organising the data before that can occur.

5.9 Quantitative Data Collection and Analysis Methods

In quantitative data interpretation and analysis, the issue is relatively direct, in that the numbers obtained from questionnaire results can be immediately input into SPSS and interrogated to create a variety of tables and charts that display the data according to ranking, percentage or another form of numerical grading. This procedure was followed in this case, with data analysed in SPSS version 21. Descriptive statistics and normality testing were performed. Cross tabulations were carried out to investigate particular aspects of the survey data that the researcher considered to be of key importance. Selected analysis was provided in graphic and tabular forms, bearing in mind the recommendations of Saunders et al. (2009):

- Type of data (scale of measurement)
- Format in which the data will be input to the analytical software
- Impact of data coding on subsequent analysis (for different data types)
- Need to weight cases
- Methods intended to be used to check data for errors

5.9.1 Data collection

One of the main objectives of this study is to identify the significant factors that have an impact on H&S performance. Data are needed to develop a framework for measuring and evaluating the H&S performance in KSA public construction industry. The questionnaire was designed to investigate and evaluate these factors, and this section presents and analyses them.

The distribution of the questionnaire used four different approaches: social networks, web links, email invitations and manual entry. The highest number of responses was 109 from the web link, which used communication apps such as WhatsApp and Blackberry chat to distribute the link. The second highest response was the email invitation, with 45 respondents. More than 200 construction company owners and managers, as well as employees, received an email from the researcher containing information about the research and three links. The first was specific to the recipient and when Survey Monkey got a response, the result appeared with his/her information. That helped with the reminder email sent to those who had not fully completed the questionnaire.

The survey was designed and distributed using Survey Monkey. It had 250 responses within six weeks of its distribution. One hundred and eighty respondents agreed to complete the questionnaire, nine refused and 61 provided no answer. In terms of descriptive statistics, the data were presented using tabulations and figures.

The second most popular method was the web link used to ask the recipient to share the questionnaire with colleagues or to unsubscribe if they do not wish to participate and thereby stop receiving emails (see Figure 5-5). The social network link, using Facebook and LinkedIn, saw the third highest number of responses (25). The last was manual entry, which was based on the same number of structured questionnaires; these were distributed to high-profile construction industry sector players. Six of the ten questionnaires were given to construction company owners who have advanced experience of using BIM in their companies and perfect understanding of KSA H&S policies and guidelines. The other four questionnaires were given to construction industry H&S professionals.

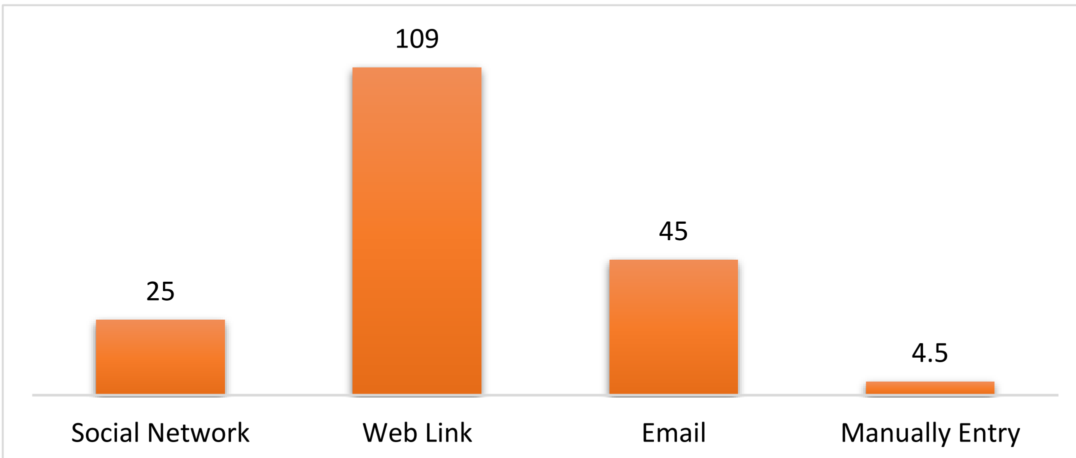

Figure 5-5: Number of responses from different approaches

The response rate started from the highest number in week one and the curve dropped dramatically to four responses in week six (see Figure 5-6). To increase the response rate, after each week an automatic email was sent to remind those who had not responded to the questionnaire. This technique was applied in the email invitation, which had more than 200 invitations. 109 out of 140 respondents completed the questionnaire, which represents almost 78% completed and 22% partial responses.

As the questionnaire was targeting three different groups, company owners, managers and employees within the construction sector in KSA, the questionnaire has different responses from the three groups (see Figure 5-7). More than half of the responses were from employees, followed by managers then owners.

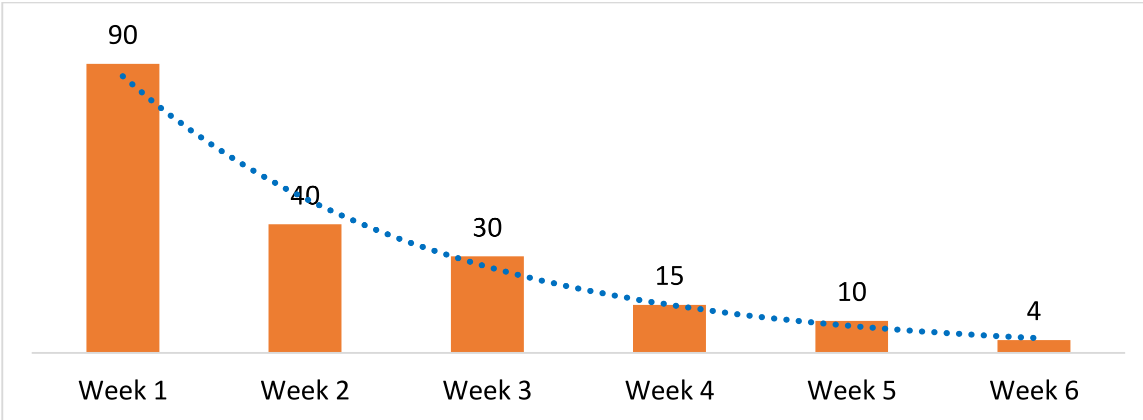

Figure 5-6: Response rate curve

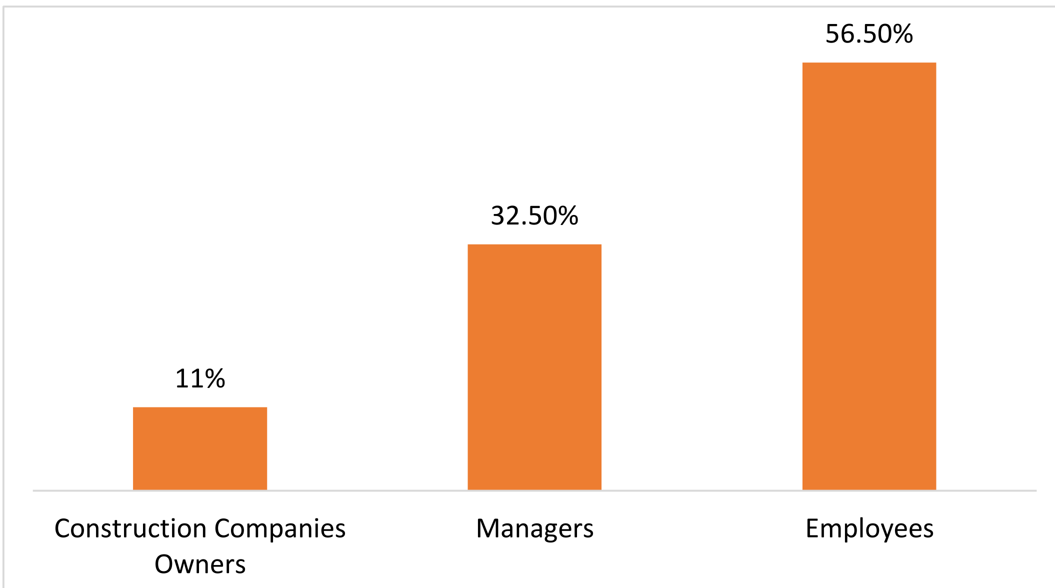

Figure 5-7: Responses from different groups

This review of the quantitative data collection method and analysis is complete. The resulting analysis appears in Chapter 6. This study now moves on to considering the methods of qualitative data analysis.

5.9.2 Qualitative data

Interviews were used to collect the qualitative data needed to meet the aims of this research. These were conducted generally at the participant's place of work. Among the ten, there was a range of management position and expertise, deliberately chosen from a list of personal contacts, to reflect the many different areas of experience and knowledge of the construction industry in KSA. As referred to, the interviewees were chosen carefully, rather than being randomly invited in a snowball manner. While the quantitative data was planned and designed to offer large numbers of participants, the qualitative data was guided by the need for input from specific experts and, therefore, the sample size was small.

Interviews were first arranged through email contact; this specified the ethical considerations applicable to those who would take part in this study – consent, anonymity, confidentiality, secure storage and permission to withdraw at any time. There was an attachment with this email, which the participants were required to sign and send back to the researcher as permission to allow the interview to proceed. Further permission had to be sought to record the interviews, as it is unethical and generally illegal to use an audio recording without the interviewee's knowledge or consent. These precautions were applied.

Method for interviews

Interviews began with the recorded question about permission being granted for the recording. Then the interview continued with the schedule of questions that are included in Appendix 3, although as in all semi-structured interviews there was the possibility that a participant might like to introduce and discuss issues that were not necessarily part of the agenda. Equally, there could be some small variation in the order of questions asked and some could occasionally be omitted if it appeared that answering them would be outside an interviewee's experience.

In addition to the audio recorder, a notebook was taken into the interview room, so that any important body language could be noted down, either at the time or immediately afterwards. Interviews were conducted in Arabic, which was the common language of all, including the researcher. After completion of each interview, the participant was thanked and the audiotape taken away for transcription. In this study, the researcher did both the transcription and translation. This is always an advantage in qualitative data, and repeated exposure to the interview, in this case both through transcription and translation, constantly familiarises the researcher with the core details of the interview. In qualitative data collection and analysis, the examination of texts should be constant and repeated. This enables the themes of the case in general and each in its turn to emerge.

5.10 Choice of Method of Analysis

At this point of the data examination, the researcher should make a choice between using a software program to help analyse the data or doing so manually. NVivo is the principal program used for qualitative analysis. Some researchers prefer to work with this program and its analytic tool, as it enables storage and breakdown of the patters to be entered under various thematic headings and subheadings. These can then form the basis of the qualitative results. NVivo is particularly useful if there is a large amount of data, as it has exceptional storage facility for different types of data, but the program has to be learned and that can delay the analysis itself, especially where there are time constraints as in a PhD. Another weakness of NVivo is that in order to code in a particular way and “save” the few words that might contribute to a theme, the text itself is broken up and away from the context it occurred in. It is often valuable when dealing with smaller amounts of data to keep the texts as complete as possible. That also helps with constant examination of and familiarisation with the texts themselves. In a small group of interviewees, all of whom have a different life and work experience on construction sites in KSA, keeping the texts intact enables the researcher to value the individuality of each contribution to the data. It was, therefore, decided to code the data manually.

There are a number of ways to achieve this, but the important issue right at the beginning is to have read the interviews so often while “mining” the data for themes to feel confident in one chosen method, as it is said that any method that the researcher has personally identified and is comfortable with is likely to produce good analysis and results. These data were analysed by the use of colour coding. Seven specific themes were common to all transcripts and, therefore, needed to be grouped in a way that was visually recognisable but that would still preserve the transcript as a document which, if necessary, could be analysed a second time in a different way. This is often a requirement when using mixed method, as there may be a need to link the results of the qualitative analysis in some way with those of the quantitative analysis.

5.10.1 Manual Colour Coding

There is a procedure for the use of colour coding in this type of analysis. Examples of each stage can be found in Appendices 4 and 5.

- Recognise the themes common to all transcripts and designate one colour for each
- Colour code each transcript to the colour coding that could be applied to each statement in the transcript. Not all statements need to be colour coded. A balance has to be found between the weight of different statements, and the strongest and clearest should be chosen
- Develop new documents of analysis, each dedicated to one of the themes
- Copy and save each of these documents (Stage 2)
- Use stage-2 documents to create the primary level of analysis

Levels of analysis can be decided at any point in the study. For this particular study, it was decided that the primary qualitative analysis should be conducted first, so as to bring forward those personal views and attitudes that may not have been fully explored in the quantitative analysis and that might further elucidate or contest issues in that analysis. In this mixed method study, the researcher chose to explore these questions by the theoretical model of survey, so as to reveal the knowledge, understanding, attitudes and beliefs of those in the KSA construction industry. It was hoped to provide some evidence on which a suggested framework for H&S could be built.

5.11 Qualitative and Quantitative Methods Compared

Surveys often rely completely on the results garnered from questionnaires. This is because this is a method that can collect the largest input in the most efficient way, particularly if those questionnaires can be remotely produced and administered online, where they are always available and where it is simple to log on for those intending to participate. All questionnaires are the same, so the researcher can be sure of standardisation across the analysis of results; moreover, using this as the primary research method can be cost effective, as there are no transport or set-up costs. The use in this study of the Survey Monkey facility added to efficiency and efficacy.

On the other hand, there are known limitations to the questionnaire method; some of these have been discussed previously, with response bias named as a possible problem. Those filling in an online questionnaire may have attitudes and intentions that are complex. Some may want to impress the reader with their knowledge and there may be evidence in this particular study that this could have happened. Others may wish to challenge, or may have a grudge, so unlike the false positives produced in the earlier challenge, they can produce false negatives. There are always challenges to validity in using this method. Some may not know or remember the answer, but feel they have to complete the questionnaire. The challenge to validity is more likely to occur if the option of “don’t know” is not included as an acceptable answer. Some may rush to fill in the questionnaire and their answers may be careless. And finally, one of the strongest challenges when using a Likert scale, as here, is that the definition of the word “extremely” may differ according to personality.

This is why, in this study, a qualitative element has been introduced, in this case in the form of interviews. The second method of analysis also has its weaknesses, not least the possibility of researcher bias. The latter is sometimes thought to be a strength of the interpretivist paradigm, as it acknowledges and provides for some of the subjectivity that is often present in the participants in quantitative methods but cannot easily be dealt with, whereas researcher bias is under the control of the researcher. Quantitative data collection and analysis, in this case, was very useful, for it enabled comparisons. Also, it provided time and understanding. Sometimes the participants need to have questions rephrased to avoid misunderstandings; sometimes they like to add their own perceptions to those of the researcher and enter into greater detail or move to a slightly different topic. Interviews can be personalised by the researcher, as he can change the order of the questions at will using his judgement, interpret body language and can also, if necessary, add probes and prompts (Gabriel, 2013).

The qualitative and quantitative methods used in this study provided several discrepancies in the results arising from the difference in data collection and analysis, others arising from the strengths and weaknesses of the different methods, as discussed above, and some reflecting the sample itself, which was different in each case.

Summry

One of the strong advantages of a mixed method study is that its results, produced in the positivist and the interpretivist paradigms, can support or contest the findings located in the other paradigm. This can lead to a number of interesting and complex discoveries with the possibility of forming a strong basis for the generation of theory, insight and practical applications. This, it is hoped, is the outcome here. Chapter 6 provides the results of the questionnaire survey and provides the results of the interviews and Chapter 7 demonstrates how the literature and findings were brought together to develop the proposed framework. It is hoped that this joint analysis adds richness and depth to the subject under study. This forms the initial section of the discussion. The second and final part of the discussion chapter examines the possibilities of using the combined findings to create a framework to support the development of H&S procedures in the construction industry in KSA.

Chapter 6. Quantitative and Qualitative Data Analysis

6.1 Introduction

This study employs a mixed method approach, combining aspects of both qualitative and quantitative data collection and analysis. This chapter first presents the qualitative data analysis, including descriptive statistics and cross tabulations (based on size and nature of firm) of the survey data, followed by factor analysis, ANOVA analysis and OLS regression analysis. The quantitative data analysis is then presented.

As the first step in analysing the survey data, the descriptive statistics are presented in narrative and chart form, including the survey question, the response rate and the percentage of respondents selecting the various options in answering each question. Following the provision of descriptive statistics, three tests of statistical analysis are performed. First, factor analysis was used to lower the number observed factors associated with H&S in the construction industry in KSA. Using one component and loadings of less than 0.8, the four remaining factors are used to conduct ANOVA and OLS regression analysis.

6.2 Quantitative Data Analysis

6.2.1 Descriptive Statistics

To ascertain the participant's general/basic knowledge of KSA H&S policies and guidelines, and to adhere to the highest ethical standards and research guidelines, the research questions were designed to elicit responses from participants with respect to questions asked with a bid of making a contribution to the study through "enhancing existing H&S processes in public construction sector projects within KSA using virtual design and construction approaches". The survey received 189 responses from business managers and public construction sector workers and employees, as well as the general public. No respondent skipped the first question.

From the survey, it was established that 95.24% (n= 180) indicated that they have general/basic knowledge of KSA H&S policies and guidelines, while 4.76% (n=9) gave a negative response (see Figure 6-1).

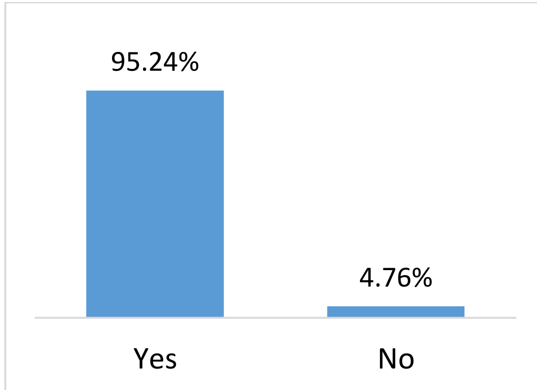

Figure 6-1: Awareness of KSA H&S policies

General information

To understand the size of the organisation and group into which a company handling different public construction sector projects falls, the questionnaire was structured to capture this information by asking about organisation size. The results indicate that 11.86% (n= 21) of the sample size represent micro-sized companies, 15.25% (n= 27) represent small-sized companies, 18.64% (n= 33) represent medium-sized firm, whereas more than 50%, specifically 54.24% (n= 96), of the sample represent large firms (see Figure 6-2). Large firms in KSA are mostly responsible for handling public construction sector projects and dominate the construction industry.

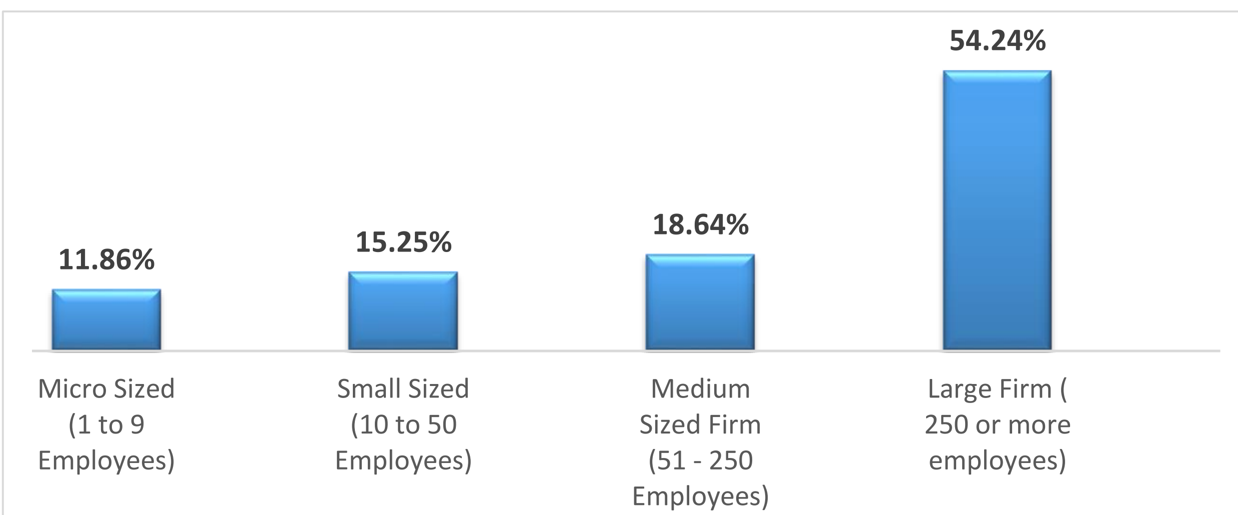

Figure 6-2: Size of construction companies

To elicit and understand the organisation's business orientation, a question asked business owners and managers about the nature of their organisation's business; it is found that most construction companies in KSA are either involved in general contracting, designing, consulting, specialist or subcontracting. The responses in percentage are as follows: 37.70% (n= 69) of KSA's construction companies, which was the dominant business activity, are in general contracting, 21.31% (n= 39) are in designing and 13.11% (n= 24) are in consulting, 18.03% (n= 33) are in specialist contracting, while the remaining 9.84% (n= 18) are in other type of business services.

To ascertain the kind of projects construction companies in KSA are involved in and group them accordingly, this question was put to business owners and managers. The results indicate that 41.67% (n=75) of respondents are involved in a combination of private and public sector projects, while 31.67% (n=57) are exclusively involved in private sector projects and 26.67% are exclusively involved in public sector projects (see Figures 6-3 and 6-4).

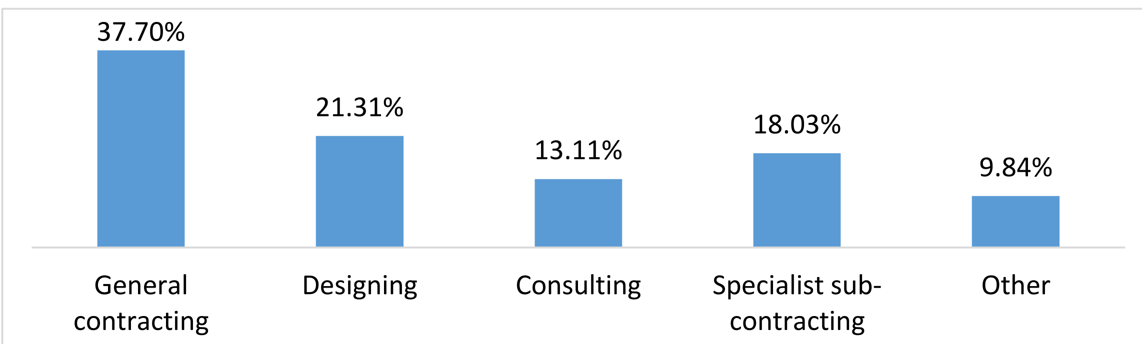

Figure 6-3: Nature of business

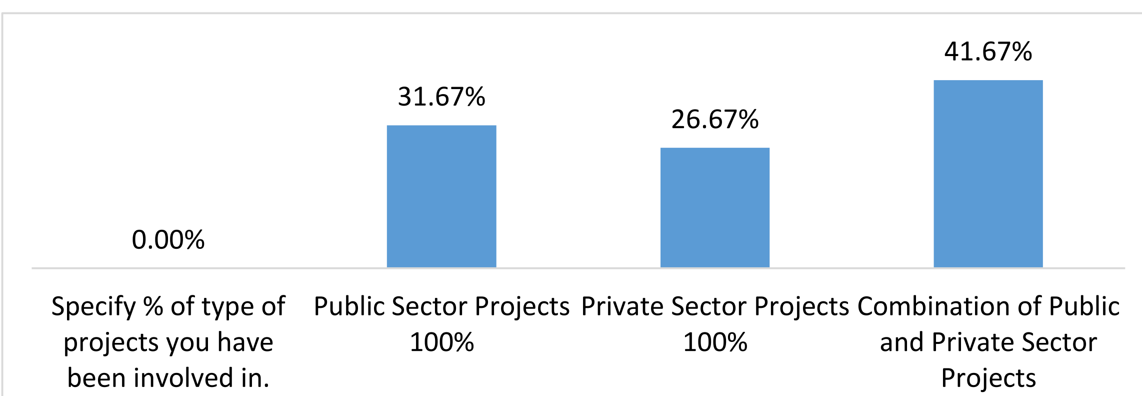

Figure 6-4: Kind of project

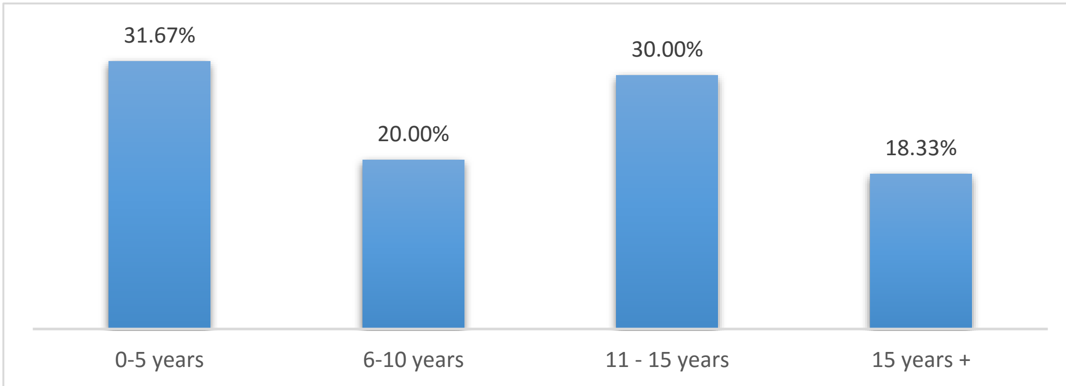

Figure 6-5: Years of experience

Regarding years of experience in the construction industry, 31.67% (n= 57) of the sample have less than five years, 20.0% (n= 36) have 5-10 years, 30.0% (n= 54) have 10-15 years and 18.33% (n= 33) have been in the construction sector for more than fifteen years (see Figure 6-5).

<u>Experience with H&S</u>

To understand the nature of the landscape in which construction companies operate in KSA, construction company managers and staff were asked if they have ever experienced H&S issues in their construction projects. The vast majority of respondents (85%) (n= 163) said that they had experienced H&S issues in construction projects, 15.0% (n= 27) said that they had not and nine respondents did not answer this question (see Figure 6-6). This finding confirms that construction companies' operational landscape in KSA is not safe and is in serious need of H&S guidelines and policies, as demonstrated by the study with 85% (n= 153) of the study's sample having experienced H&S issues in their construction projects.

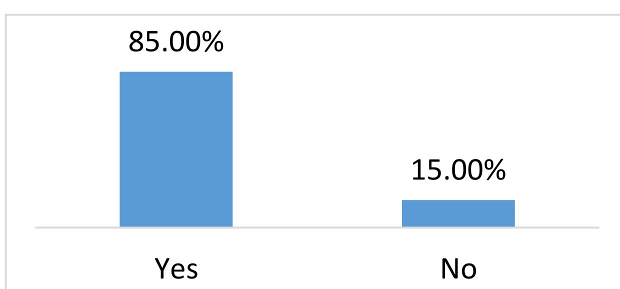

Figure 6-6: Experience of a H&S accident

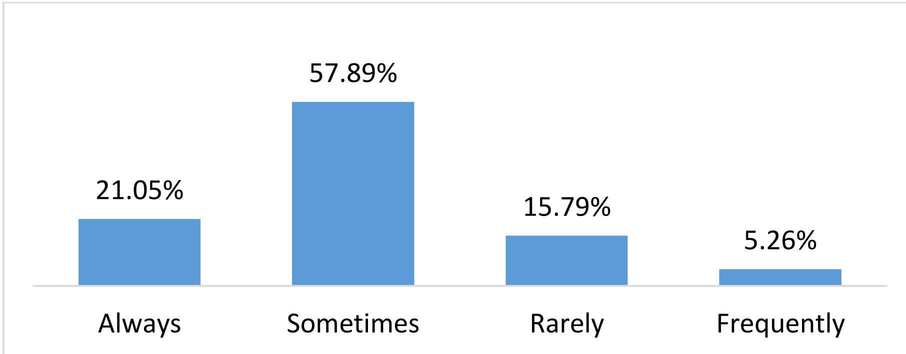

Figure 6-7: Frequency of H&S safety issues

This question was asked to ascertain the frequency of H&S safety issues in construction projects in KSA. The responses received from construction company owners, managers and staff members show that 21.05% (n= 36) of the study's sample said that they always experience H&S issues during their public construction sector projects, 57.89% (n= 99) said sometimes, while 15.79% (n= 27) said rarely and 5.26% (n= 9) said frequently (see Figure 6-7). Hence, this study finds that more than 50% of public construction sector project have experienced H&S issues, which implies the need for an adequate and effective H&S policy guideline to regulate KSA public construction sector.

<u>Common H&S hazards</u>

The next question was asked to determine the H&S hazards common to workers in the public construction sector. It was discovered that the most common H&S hazards are slips, trips and falls, 63.79% (n = 111), followed by heat exhaustion, 56.90% (n = 99), hazardous substances, 51.72% (n = 90) and structural collapse and accident in excavation, 48.28% (n = 84). Other less common forms of hazards are also identified, such as manual handling, 43.10% (n = 75), noise and vibration, 43.10% (n = 75), plant and equipment, 41.38% (n = 72), fall from height, 36.21% (n = 63), electrical hazard, 36.21% (n = 63), crane collapse and falling off load, 27.59% (n = 48), asbestos and chemical exposure, 24.14% (n = 42) and fire outbreak, 22.41% (n = 39). These results indicate that many different hazards are common in the industry (see Figure 6-8).

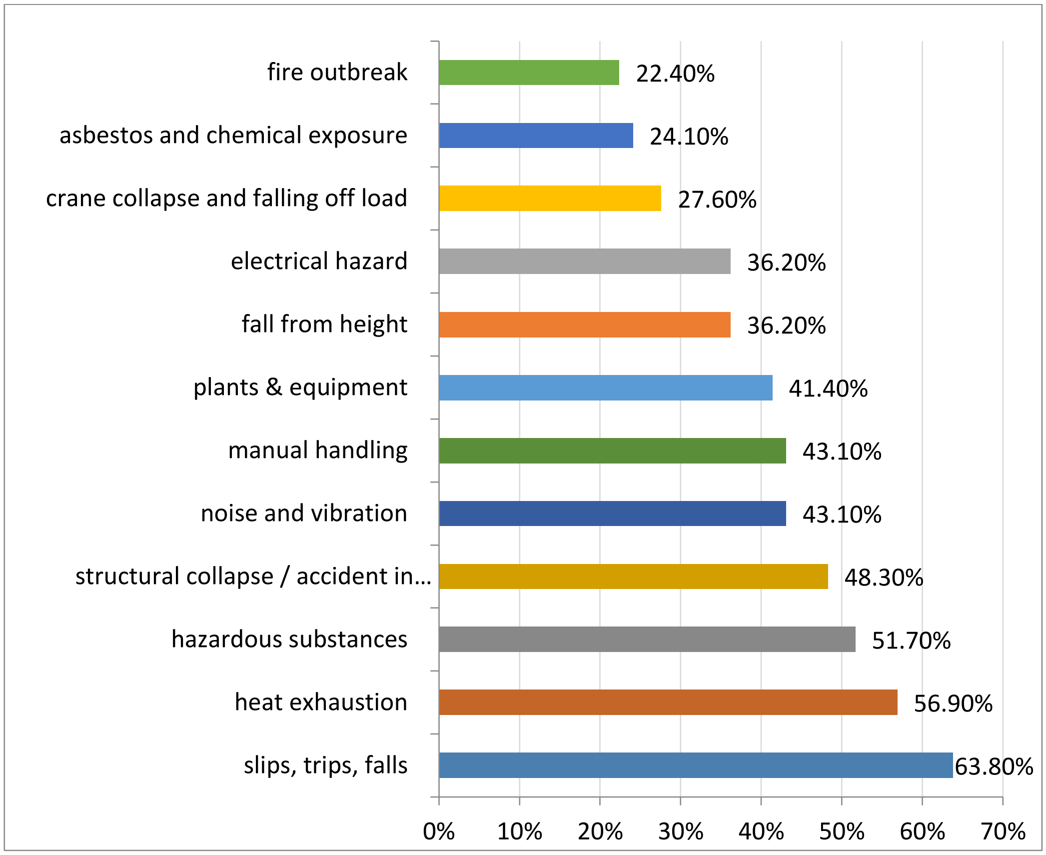

Figure 6-8: Common H&S hazards

<u>Safety Practice</u>

This question was asked to ascertain the use of H&S safety policies and practices. It was discovered that companies with construction safety policies and practices fully integrated and widely observed account for about 31.67% (n= 57) of the study sample, while many other construction companies which have construction safety policies and practices in place, but lack full integration, account for 50.0% (n= 90) of respondents (see Figure 6-9). Moreover, some other companies with ad hoc approaches to construction safety and no formal policy, but that have occasional construction safety reviews, account for about 13% (n= 24), whereas some companies have no construction safety policies and programmes at all, 5.00% (n= 9). Thus, a strong majority of respondents (68.33%) express the opinion that their firms do not implement H&S policies. This finding indicates that the KSA construction companies sampled lack integration and implementation of safety policies and programmes but use an ad hoc approach to combat H&S issues. This also shows that the Saudi Arabian government has failed in its responsibility to monitor and ensure standardisation in the public construction sector, as the lack of H&S policies in these companies portrays the government commitment and attitude to the effectiveness of H&S in the construction sector in a bad light.

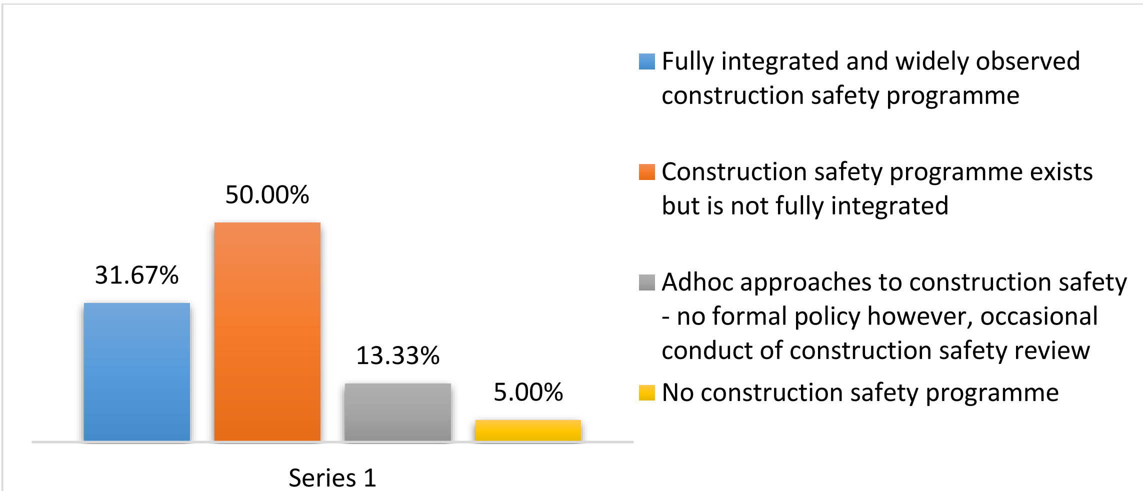

Figure 6-9: Use of H&S

To identify the different H&S policies and practices currently in use, this question was put owners, managers and employees. It was found that companies whose site workers undertake induction training represent 68.33% (n = 123) of the sample. This was followed by companies that have due process in place to investigate all reported H&S incidents, 66.67% (n = 120), companies that maintain an on-site register to record any hazards reported by workers, 58.33% (n = 105), then companies that have designated project safety personnel to manage on-site safety, 56.67% (n = 102). Companies that analyse site safety hazards in the pre-construction stage represent 55.00% (n = 99), others that follow the "safety by design" process by analysing safety hazards in the pre-construction stage represent 36.67% (n = 66) (see Figure 6-10).

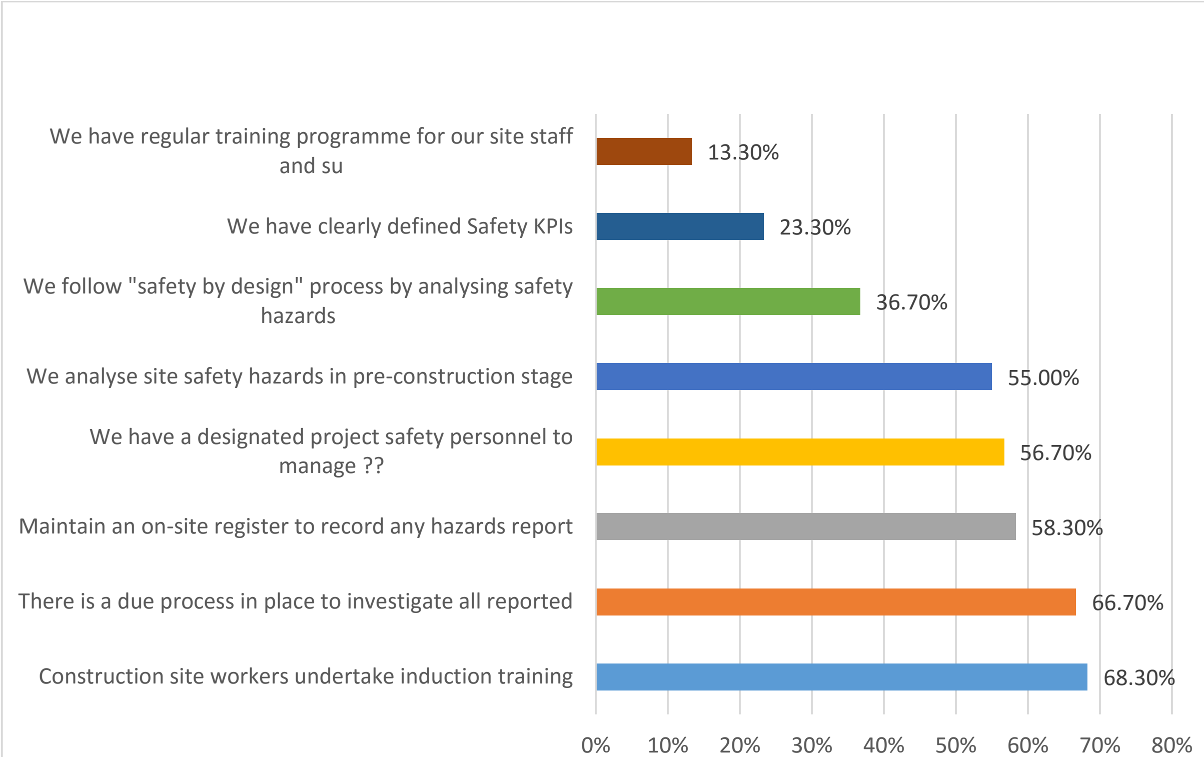

Figure 6-10: Current H&S practices

There are also companies that have clearly defined safety KPI, representing 23.33% (n = 42) of the study sample, while those that organise regular training programme for site staff and subcontractors represent 13.33% (n = 24). The results indicate that most construction companies in KSA lack the integration of H&S policies and guidelines, but through their ad hoc safety approaches have some basic or partial H&S policies in place. This study also established that most of the construction companies surveyed do not have a full integration of the complete and standard H&S policies and guidelines governing public construction sector companies in KSA.

6.2.2 Factor Analysis

Construction company owners, managers and employees were asked to rate factors with respect to their importance to H&S policies and programmes. The respondents were provided with 18 factors to rate using the five-point Likert scale. The 18 factors related to H&S are as follows (with the variable name used for analysis shown in parenthesis):

- Better enforcement of regulation and laws (BetEnfor)

- Cost of implementing H&S measures (Cost)
- 3D, 4D and 5D visualisation/simulation (DVis)
- Safety measures incorporated into design phase (SafMeas)
- Proactive approaches, e.g. hazards assessment and safety planning (Proactive)
- Management of data of all processes, including H&S (DataMan)
- Better communication devices for efficient information sharing (GoodCom)
- Strong and clear communication link between all stakeholders (StakeCom)
- Safety training programme available to all staff across organisation (SafTrainProg)
- Simpler modes of information exchange (InfoExch)
- Good safety leadership abilities in site supervisors (SafLead)
- Regular site safety audits (RegSafAudit)
- Regular on-site safety meetings (RegSafMeet)
- Employee education and training (Knowledge)
- Personnel's responsibility (PerResp)
- Safety equipment and gear in hazardous environments (Equip)
- Changing behaviour of employees towards H&S measures (ChangeBeh)
- H&S incident reporting culture (HSIncidRep)

The factors are presented using descriptive statistics, including frequencies of the responses and weighted means of the responses. In the next step of analysis, these 18 factors were subjected to factor analysis for dimension reduction and the results used for ANOVA and OLS regression analysis. The purpose of using factor analysis in this study is to assess patterns in the data provided by the respondents in regard to these 18 factors, in an effort to reduce the number of factors to be studied. Thus, factor analysis is used to determine which, among the 18 factors, have the most significance in regard to the phenomenon being studied. The responses for each factor are provided in the tables below, in which 1-5 represent a scaled response with 1 being “extremely low” and 5 “extremely high”.

For a better comparison of the importance of these variables, the weighted mean was calculated for each response. To calculate the weighted mean, the number of responses was multiplied by the associated weight of the response (from 1-5). This process allowed the researcher to compare the importance of the 18 factors. As Table 6-1 below shows, most items received a reasonably high rating and the range of means was quite limited, with the lowest being 3.53 for "Better enforcement of regulation and laws" and "Safety measures incorporated into design phase", and the highest mean rating being 3.9 for "Better communication devices for efficient information sharing".

Table 6-1: Factor analysis

Safety Programme Factors	**N**	**Min**	**Max**	**Mean**	**Std. Deviation**
Better enforcement of regulation and laws (BetEnfor)	180	1	5	3.53	1.221
Cost of implementing H&S measures (Cost)	180	1	5	3.82	1.193
3D, 4D and 5D visualisation/simulation (DVis)	180	1	5	3.70	1.246
Safety measures incorporated into design phase (SafMeas)	177	1	5	3.53	1.336
Proactive approaches, e.g. hazard assessments and safety planning. (Proactive)	177	1	5	3.78	1.226
Management of data of all processes, including H&S (DataMan)	177	1	5	3.58	1.295
Better communication devices for efficient information sharing (GoodCom)	180	1	5	3.90	1.047
Strong and clear communication link between all stakeholders (StakeCom)	177	1	5	3.85	1.180
Safety training programme available to all staff across organisation. (SafTrainProg)	177	1	5	3.58	1.269
Simpler modes of information exchange (InfoExch)	177	1	5	3.66	1.275
Good safety leadership abilities in site supervisors (SafLead)	174	1	5	3.66	1.280
Regular site safety audits (RegSafAudit)	181	1	5	3.61	1.249
Regular on-site safety meetings (RegSafMeet)	180	1	5	3.68	1.119
Employee education and training (Knowledge)	185	1	5	3.75	1.154
Personnel's responsibility (PerResp)	181	1	5	3.64	1.265
Safety equipment and gear in hazardous environments (Equip)	180	1	5	3.74	1.159
Changing behaviour of employees towards H&S measures (ChangeBeh)	176	1	5	3.81	1.148
H&S incident reporting culture (HSIncidRep)	178	1	5	3.87	1.115

6.2.3 Respondents' Ratings of H&S in their Organisation

Most items in this question were ranked highly (there was a very narrow range of rankings from 3.53 to 3.90). Better communication devices for efficient information sharing (GoodCom) was considered the most important factor for H&S on construction sites (mean 3.90), followed by strong and clear communication link between all stakeholders (StakeCom) with a mean of 3.85. Cost of implementing H&S measures (Cost) was the third most important with a mean of 3.82. The items ranking lowest were safety measures incorporated into design phase (SafMeas) and better enforcement of regulation and laws (BetEnfor), each with 3.53.

6.2.4 Factors considered responsible for H&S on Construction Sites

Next, respondents were asked about providing H&S training for their workers. 89.47% (n = 153) said that they provide this H&S training, while 10.53% (n = 18) said that they do not (see Figure 6-11). This study finds that most construction companies in KSA provide H&S training for their employees but that a gap exists, which is the lack of proper implementation and utilisation of H&S policies and guidelines in construction projects on site by employees.

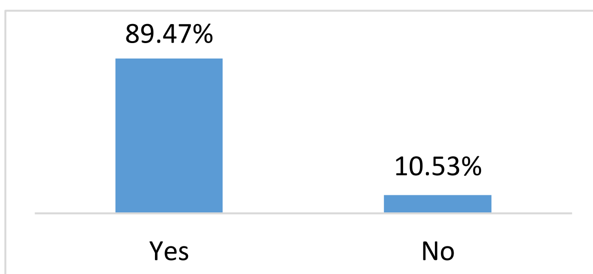

Figure 6-11: Provide H&S training

Respondents were asked to identify factors which they consider responsible for H&S issues on site. 35.00% (n = 63) consider a lack of effective communication highly responsible for most H&S issues, followed by 28.33% (n = 51) agreeing that lack of effective site planning was also highly responsible for H&S issues, followed by 32.76% (n = 57) revealing that poor implementation of H&S implementation procedures were responsible for H&S issues. 27.12% (n = 48) believe that lack of regulation is responsible for H&S construction site issues, while 25.00% (n = 42) regard human error as a high contributory factor to H&S issues, 29.31% (n =

51) indicate that a lack of H&S reporting culture was a high contributing factor, followed by 37.29% (n = 66) who believe that lack of consideration of H&S in planning and design stages is responsible for H&S issues in construction sites in KSA.

Next, 35.59% (n = 63) record that the Saudi Arabian multicultural system is highly responsible for H&S issues, while others, representing 33.33% (n = 60), assert that a low education level was responsible for H&S issues; finally, 27.12% (n = 48) believe the multilingual nature of KSA construction sector is highly responsible for H&S issues encountered (see Figure 6-12). This study finds that Saudi Arabian construction companies lack full knowledge of the public construction sector landscape and also that most construction company employees are unaware of H&S policies and practices, and do not adhere to H&S policies and guidelines when carrying out construction projects. This is shown by their lack of consideration of H&S in planning and design stages and their poor implementation of H&S procedures. Other factors were inherent in the geographical setting and the people's ideology, as established by their multilingual nature, multicultural landscape and human error.

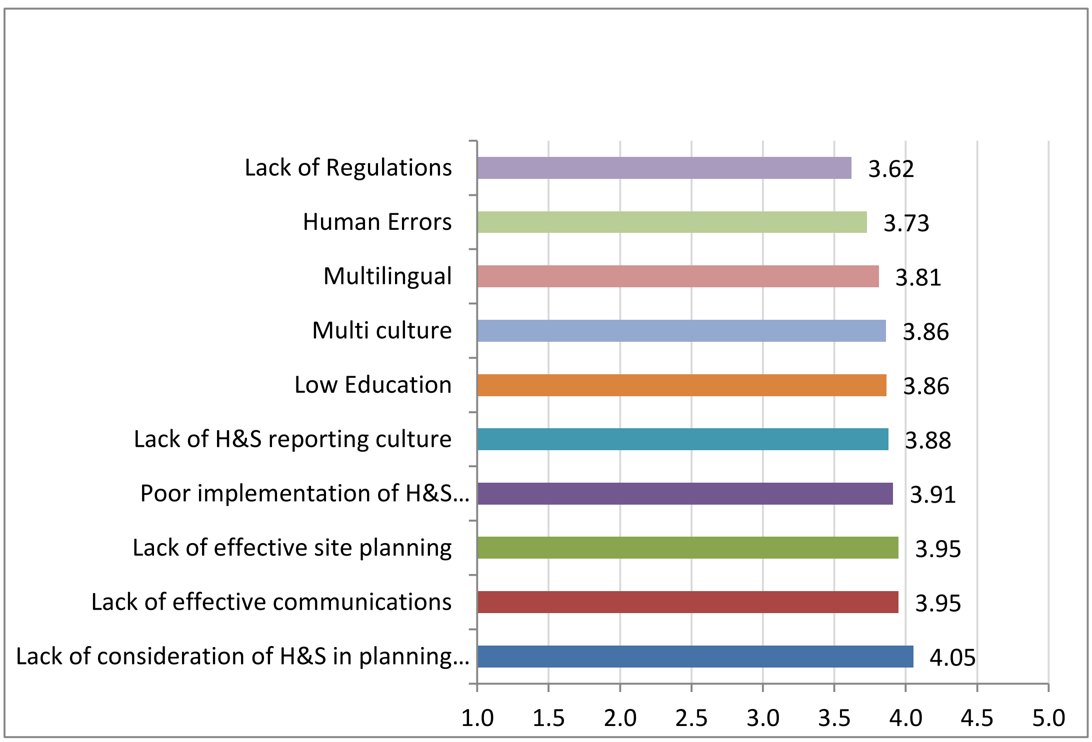

Figure 6-12: Factors considered responsible for H&S issues

6.2.5 Safety Training

In assessing the training methods employed and their level of effectiveness, 73.33% (n = 132) of the study sample reveal that on-site safety training and education is the most effective method of training their employees on H&S rules, policies and guidelines; 16.67% (n = 30) reveal that the most effective H&S training method is online training; and 10.00% (n = 18) believe that a certification programme for site safety is the most effective method of training their construction site workers and employees (see Figure 6-13). This study finds that most of the sample chose on-site safety training and education as the most effective method of training in H&S policies and guidelines.

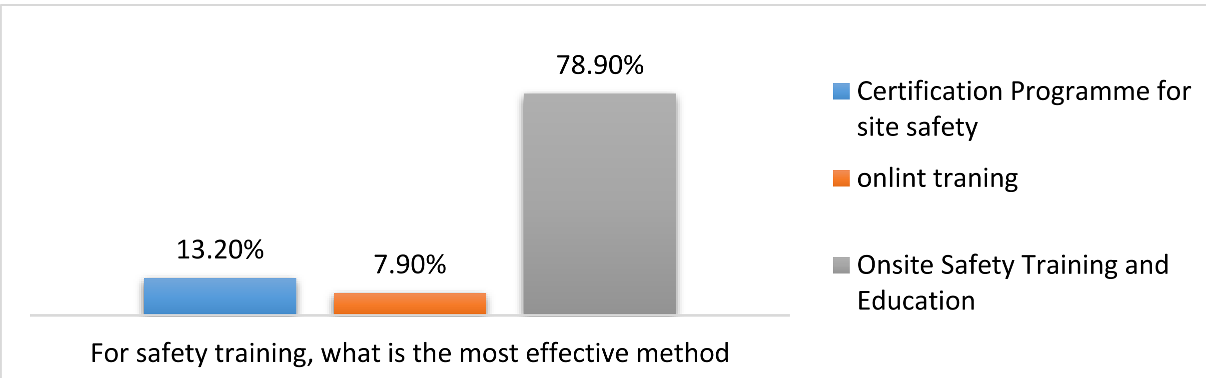

Figure 6-13: Safety training – most effective method

6.2.6 Impact of Investment in Safety Programmes

91.67% (n = 165) of respondents agree that investment in safety programme will positively impact project schedule and 73.33% (n = 132) agree regarding project budget (see Table 6-2). Next, 81.67% (n = 147) agree that it will positively impact company profitability and project quality 77.97% (n = 138), while 78.33% (n = 141) agree that it will positively impact safety KPI (e.g. injuries) and 76.67% (n = 138) agree that earlier involvement of contractors in design and construction stage will positively impact construction projects. 78.33% (n = 141) agree that BIM will positively impact on-site construction safety and 75.00% (n = 135) agree that use of off-site construction techniques and processes will positively impact construction safety, while 67.80% (n = 120) agree that the use of mobile tools, such as phones and tablets, could positively impact construction safety. This study finds that there is a significant and direct positive impact

Table 6-2: Impact of investment in safety programmes

Questionnaire item	Type of impact	N	%
How will investment in safety programmes impact project schedule?	Positive impact	165	91.70%
	Negative impact	9	5.00%
	No impact	6	3.30%
How will investment in safety programme impact project budget?	Positive impact	132	73.30%
	Negative impact	27	15.00%
	No impact	21	11.70%
How will investment in safety programme impact company's profitability?	Positive impact	147	81.70%
	Negative impact	21	11.70%
	No impact	21	6.70%
How will investment in safety programme impact project quality?	Positive impact	138	78.00%
	Negative impact	18	10.20%
	No impact	21	11.90%
How will investment in safety programme impact safety KPI (e.g. injuries)?	Positive impact	141	78.30%
	Negative impact	15	8.30%
	No impact	24	13.30%
What impact earlier involvement of contractors in design and construction stage can make on construction projects?	Positive impact	138	76.70%
	Negative impact	9	5.00%
	No impact	33	18.30%
How can BIM impact on-site construction safety?	Positive impact	141	78.30%
	Negative impact	24	13.30%
	No impact	15	8.30%
How does use of off-site construction techniques and processes impact construction safety?	Positive impact	135	75.00%
	Negative impact	21	11.70%
	No impact	24	13.30%
How could use of mobile tools (e.g. phones and tablets) impact construction safety?	Positive impact	120	67.80%
	Negative impact	21	11.90%
	No impact	36	20.30%

of investment on H&S on construction projects in KSA construction sector. This was established by the responses received, while studies have shown that investment in H&S can greatly impact construction projects.

6.2.7 Risk Assessment

To ascertain the attitude of respondents to H&S policies and guidelines, they were asked if they prepare formal risk assessment and a method statement for any of their projects. 63.33% (n = 114) said yes, while 36.67% (n = 66) said no (see Figure 6-14). Hence, this study finds that a large portion of the Saudi Arabian construction sector does not adhere to H&S policies and guidelines.

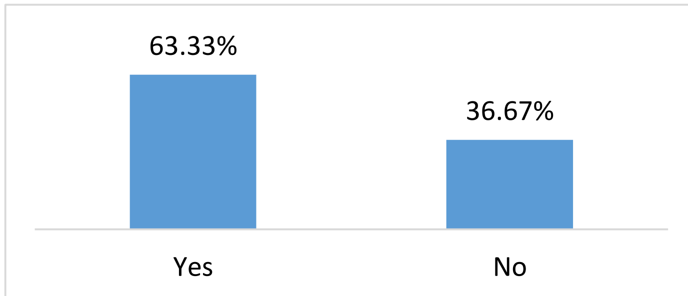

Figure 6-14: Organisations preparing formal risk assessment

6.2.8 Using BIM

To ascertain the use of technology and the advantages that technological advancement has on H&S, respondents were asked if they used BIM tools and technology in carrying out their construction projects. The majority, 61.02% (n = 108) said yes, while 38.98% (n = 69) said no (see Figure 6-15). The study finds that more than one-third of construction companies in KSA do not take advantage of computer and technological advancement in carrying out their various projects. This shows that they are either unaware of the advantages that BIM technology has to offer their organisation or are lacking the wherewithal to use the tool/technology properly.

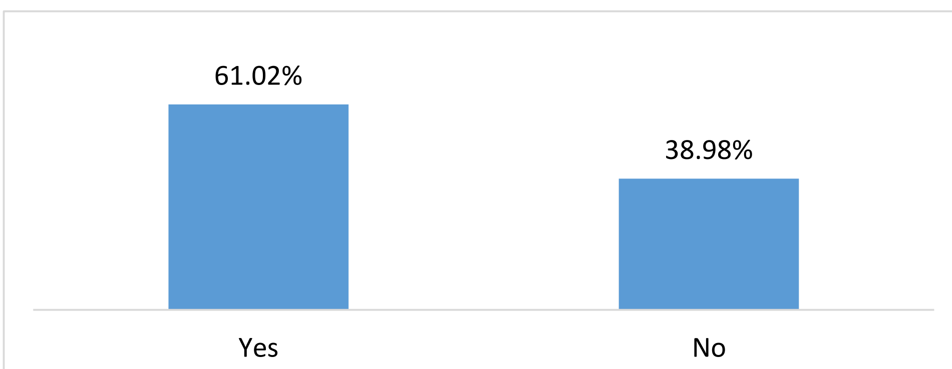

Figure 6-15: Organisations using BIM

The survey solicited the purpose of BIM within their business. 21.57% (n = 33) said that their organisation uses BIM for project planning purposes, 13.73% (n = 21) for visualisation, while 13.73% (n = 21) said that their organisation uses it for design purposes (see Figure 6-16).

Additionally, 13.73% (n = 21) said that their organisation uses BIM for sustainability purposes, 9.80% (n=15) for site planning purposes, while 5.88% (n = 9) said that their organisation uses it for estimation purposes. Finally, 1.96% (n = 3) said that their organisation uses BIM for clash detection in their construction projects, with 1.96% (n = 3) doing so for pre-fabrication or off-site manufacturing purposes. None of the respondents use BIM for facility management purposes. This study finds that most respondents use BIM tools for project planning, while some do so for visualisation, design and for sustainability purposes. BIM is a multipurpose tool that can be used for all of the above-mentioned purposes, but most construction companies in KSA only use it for just a single purpose, thereby limiting its ability to make a difference. The study also finds that most construction companies in KSA do not use the BIM tool for all of their construction needs because they lack the technical know-how of the functionality of the tool.

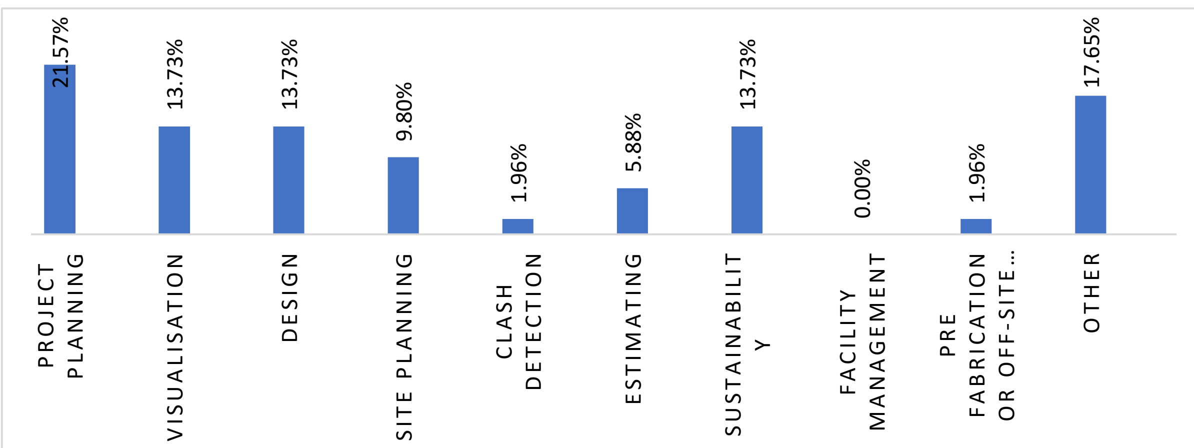

Figure 6-16: Use of BIM technology among AEC

The next question was asked to understand current understanding and knowledge of BIM. 46.30% (n = 75) said that they had basic understanding of BIM, 31.48% (n = 51) a good understanding and 11.11% (n = 18) advanced understanding, while 11.11% (n = 18) had no understanding of BIM at all (see Figure 6-17). Therefore, the results indicate that only very few construction companies have advanced knowledge and understanding of BIM, with almost half of the study sample having basic knowledge only. This finding aligns itself with previous assertions made within this study that most construction companies in KSA do not utilise the full functionality nor take advantage of the BIM technology because they lack the technical know-how and understanding to do so.

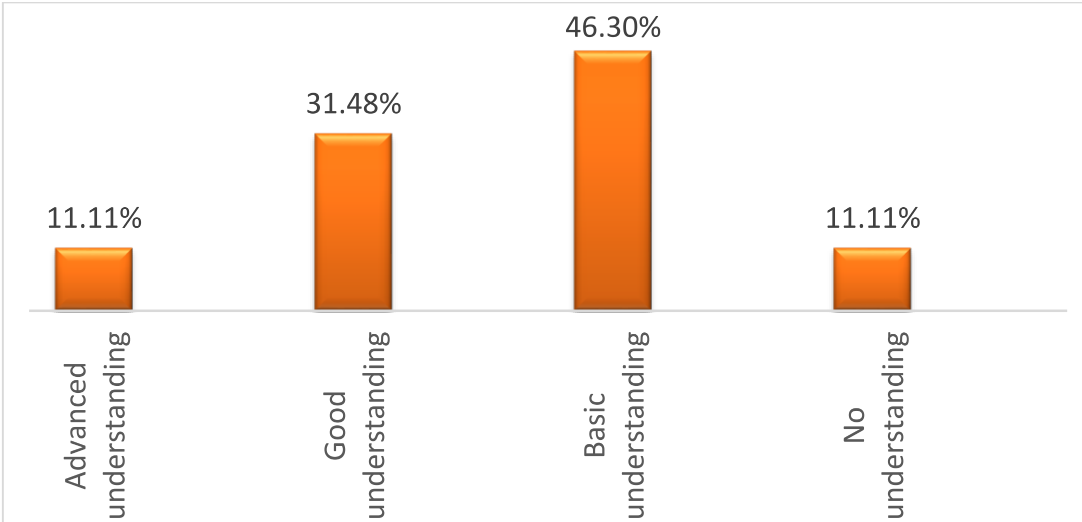

Figure 6-17: Current understanding and knowledge of BIM

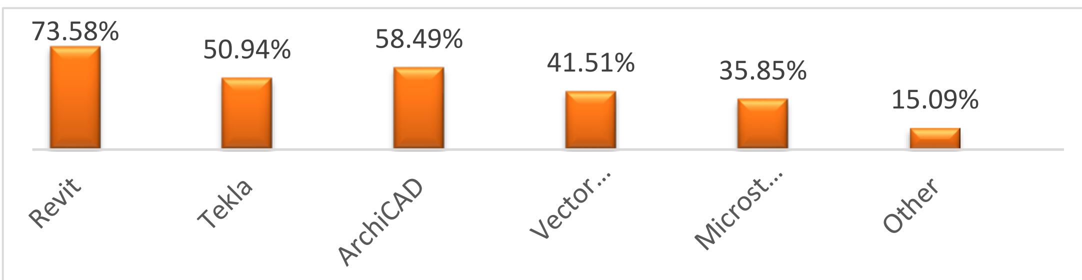

Figure 6-18: Familiarity with BIM brands

The next question elicited responses on the organisations knowledge of the various BIM software's and application packages available. The results indicate that 73.58% (n = 117) are familiar with Revit, while 58.49% (n = 93) are familiar with Archicad and 50.94% (n = 81) are familiar with Tekla (see Figure 6-18). Another 41.51% (n = 66) is familiar with Vectorworks, 35.85% (n = 57) is familiar with Microstation and 15.09% (n = 24) is familiar with some other BIM software and packages. This finding shows that most KSA construction companies have a general knowledge of BIM or at least at the level of being familiar with it.

6.2.9 BIM as an Important Tool for Site Induction

The next question solicited opinions of the use of BIM as an important tool for site induction, considering the multilingual and multicultural nature of the Saudi Arabian construction sector. 37.29% (n = 66) strongly agree that BIM is an important tool for site induction, regardless of the multilingual and multi-cultural nature of the sector, while 50.85% (n = 90) agreed, 8.47% (n = 15) were indifferent, 1.69% (n = 3) disagreed and 1.69% (n = 3) gave other reasons (see Figure 6-19). No one strongly disagreed with the importance of BIM as a site induction tool, regardless of the cultural and lingual landscape of KSA. This study finds that the BIM software and packages are very important tools for site induction, regardless of the cultural and lingual landscape of KSA construction sector.

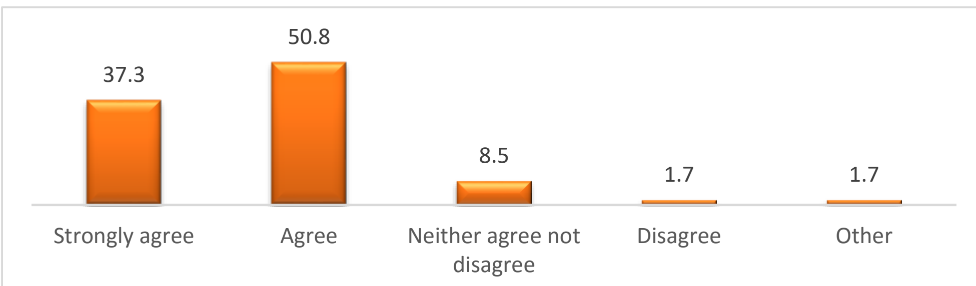

Figure 6-19: Do you consider BIM an important tool for site induction?

6.2.10 Integration of BIM into Building Regulation for Management

The next question was asked to understand the importance of BIM integration into building regulation as a positive development to the management of H&S and also to assess the potential BIM has to check for compliance with regulations on H&S risk. The results indicate that 32.20% (n = 57) strongly agree that the integration of BIM into building regulation is a positive development to the management of H&S and also has the potential to check for compliance with regulations on H&S risk, 55.93% (n = 99) agree, 8.47% (n = 15) are indifferent to the question and 3.39% (n = 6) state other reasons (see Figure 6-20). This demonstrates that the integration of BIM into building regulation is a positive development to the management of H&S and also has the potential to check for compliance with regulation on H&S risk in KSA construction sector.

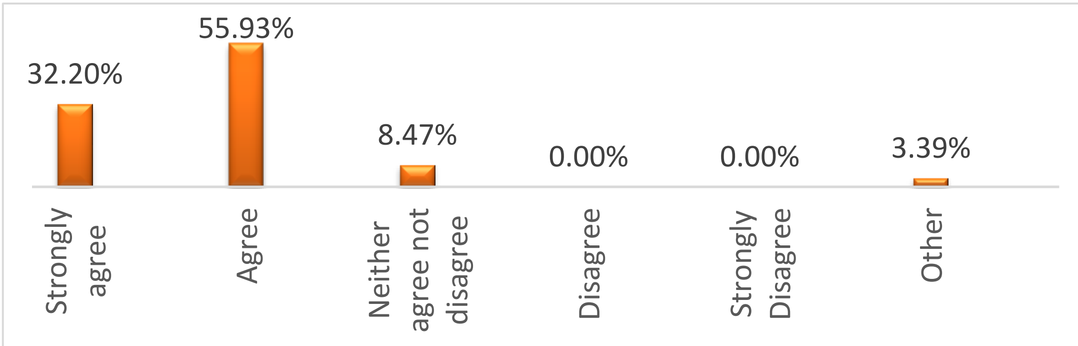

Figure 6-20: Integration of BIM into building regulation to the management of H&S

6.2.11 Benefits Derived from Implementation of BIM in Management of H&S

Owners and managers were asked how they would describe the benefits they have derived from the implementation of BIM in the management of H&S within their organisation. 70.91% (n = 117) said that BIM eliminates lost man-hours, 78.18% (n = 129) said it eliminates accidents, 74.55% (n = 123) said it improves communication, 70.91% (n = 117) said it improves construction safety, 50.91% (n = 84) said it reduces cost and 5.45% (n = 9) gave some other reasons for the benefit derived from the implementation of BIM in their organisation (see Figure 6-21). This study finds that a majority of the study sample sees benefits in the use of BIM in eliminating accidents and improving communication.

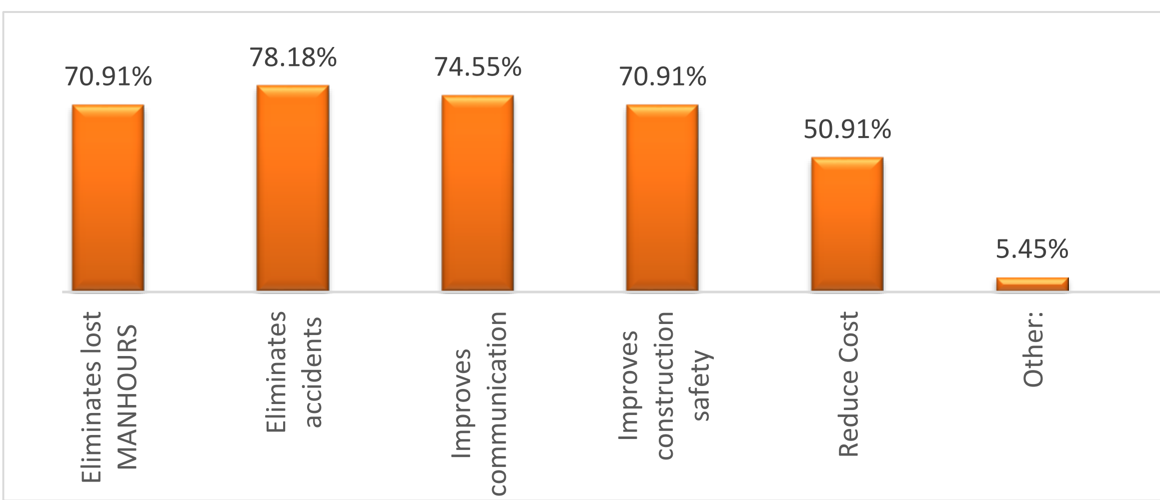

Figure 6-21: Benefits of implementation of BIM in management of H&S

6.2.12 Barriers to Full Implementation of BIM in Management of H&S

Respondents were asked to identify the barriers to BIM implementation in the management of H&S in an organisation. 86.44% (n = 153 said that education and training, 69.49% (n = 123) said behavioural change, 62.71% (n = 111) said cost of implementation, 55.93% (n = 99) said information exchange, 45.76% (n = 81) said the time required to train staffs and 5.08% (n = 9) stated other reasons (see Figure 6-22). This study finds that the greatest challenge and obstacle to the successful and effective implementation of BIM as a tool for the management of H&S in an organisation is education and training, followed by behavioural change and cost of implementation.

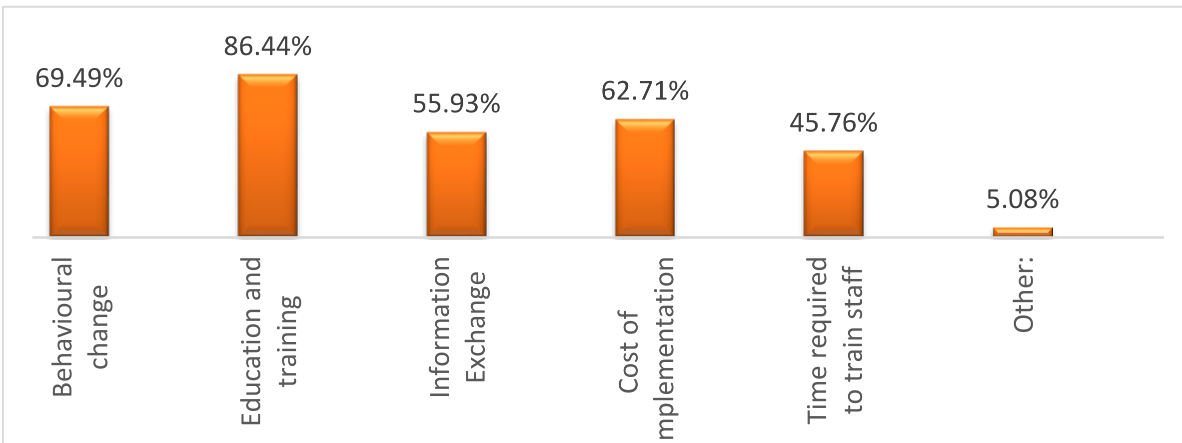

Figure 6-22: Barriers to BIM implementation in management of H&S

6.2.13 Size of Organisation – Cross Tabulations

In this section, some of the key questions in the survey are broken down according to size of organisation, to examine whether that factor is an important variable in relation to attitudes and experiences in relation to BIM.

<u>Size of Organisation and Type of Work</u>

Micro-sized organisations were largely carrying out general contracting (57%) and “other” (29%). Small-sized organisations were carrying out a mixture of all types of work, with the two largest (“general contracting” and “consulting”) each representing about one-third of their work (see Figure 6-23). Medium-sized firms also had a mixture of work, with the two largest shares being general contracting and specialist subcontracting (each around 27%).

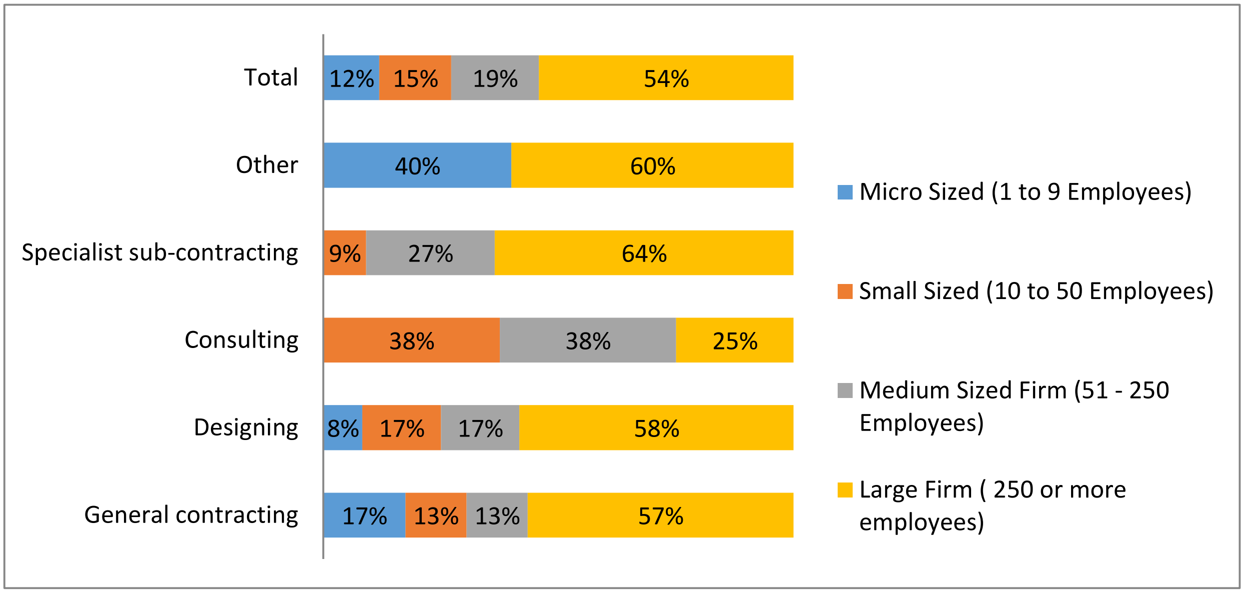

Figure 6-23: Size of organisation by nature of business

<u>Size of Organisation and Sector of Work</u>

Public sector projects make up nearly half of the work (44%) for small-sized firms, but only around one-third of the work for firms of other sizes (see Figure 6-24). Private sector work was most important for micro-sized organisations, making up 43% of their work. Private sector work made up just over a quarter of the work of large and medium-sized firms, but just 11% of that of small-sized firms.

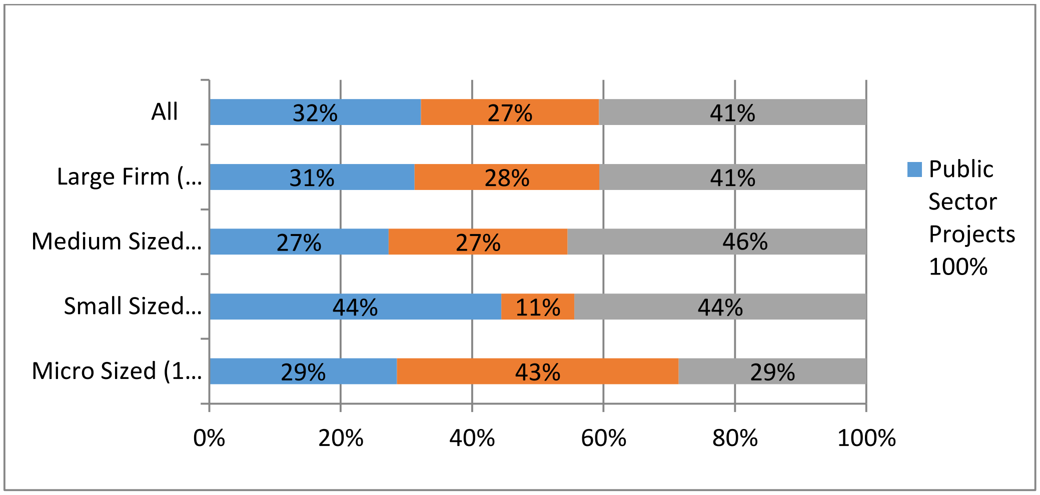

Figure 6-24: Sector of work by size of organisation

<u>Size of organisation and years of experience</u>

Respondents from medium-sized firms (51-250 employees) have the longest experience (36% with 15+ years' experience and the same proportion with 10-15 years' experience). Respondents from micro-sized firms have the least experience, with 57% saying that they have less than five years' experience (see Figure 6-25).

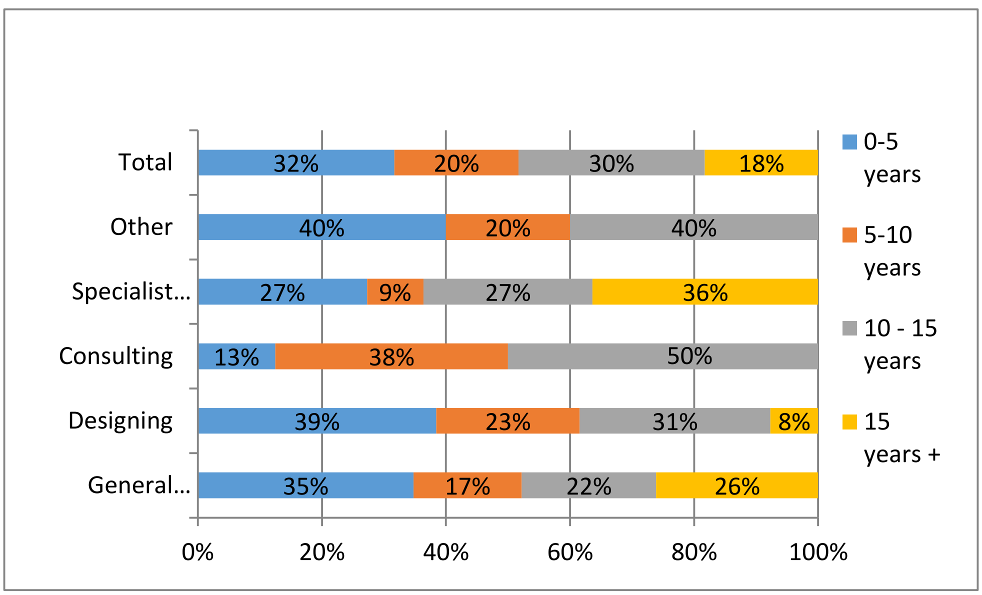

Figure 6-25: Years of experience by nature of business

Size of organisation and frequency of H&S issues

Micro organisations were least likely to say that they experience H&S issues (no respondents in this category said “always” and 55% said “rarely”). Firms with 10-50 employees were most likely to say that they “always” have H&S issues but medium and large firms do not vary greatly in this respect, with 27% and 22%, respectively, saying that they “always” have H&S issues (see Figure 6-26).

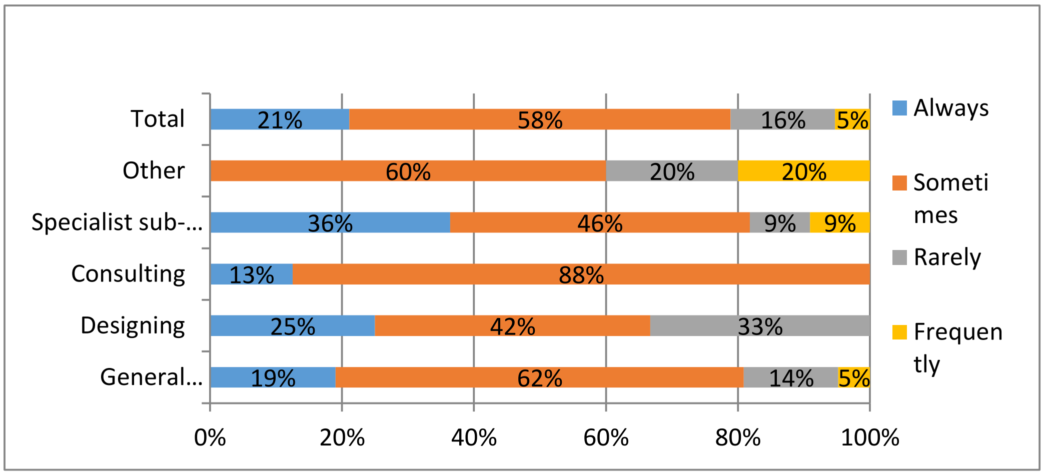

Figure 6-26: Frequency of H&S issues by nature of business

Size of organisation and use of BIM

There is a clear relationship between size of organisation and use of BIM, with nearly three-quarters of large firms using BIM and just over half of medium- and small-sized firms using it. Less than one-third of micro-sized firms are using BIM (see Figure 6-27).

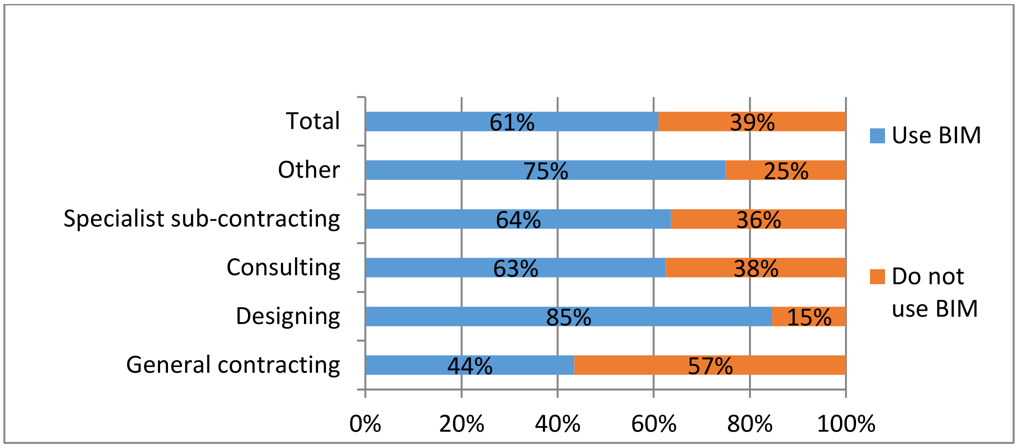

Figure 6-27: Use of BIM by nature of business

<u>Size of organisation and (self-rated) understanding of BIM</u>

Small firms are most likely to report having a good or advanced understanding of BIM (63% in total). Micro-sized firms have the lowest level of understanding of BIM. Larger firms have the highest levels of use but not the highest levels of understanding (see Figure 6-28). It is perhaps interesting to note that there is not as a simple relationship between use and understanding as might be expected.

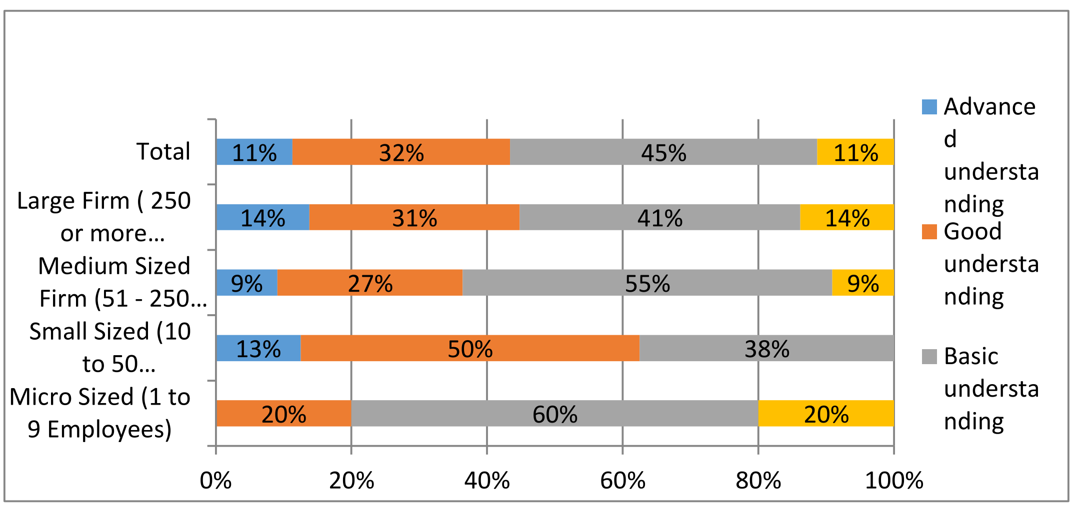

Figure 6-28: Understanding of BIM by size of organisation

Size of organisation and factors considered responsible for H&S

Respondents were asked to score a number of factors, from 1 to 5 with regard to what they consider responsible for H&S issues on construction sites. The items are shown below, from left to right in descending order of importance. The most important is lack of consideration of H&S in planning and design stages (mean 4.05), followed by lack of effective communications and lack of effective site planning (both on 3.95), poor implementation of H&S implementation procedures; low education, multicultural aspects, multilingual issues, human factors and lack of regulations.

There was some variation according to firm size: “lack of effective planning” was joint top for micro-sized firms along with “poor implementation; “multiculture” was joint top for small firms, with lack of consideration of H&S in planning” (both on 4.11); lack of effective planning was the top item for medium-sized firms, along with “lack of H&S reporting”.

Size of Organisation and H&S Practices

The top eight factors were used for comparison by size. Larger firms are more likely to have construction workers undertake induction training (78.10%), followed by medium-sized firms (63.6%). Small- and micro-sized firms had similar proportions undertaking induction (see Table 6-3). Large firms were most likely to undertake all of the H&S practices mentioned in the question, while micro-sized firms are least likely to be undertaking most of the H&S practices listed (see Table 6-4).

Table 6-3: Size of organisation and factors considered responsible for H&S

Size of construction company		Lack of consideration of H&S in planning and design stages	Lack of effective communications	Lack of effective site planning	Poor implementation of H&S implementation procedures	Lack of H&S reporting culture	Low education	Multiculture	Multilingual	Human error	Lack of regulations
Micro sized (1-9 employees)	Mean	3.71	3.86	4.14	4.14	3.71	4.00	3.57	3.86	3.50	3.43
	N	21	21	21	21	21	21	21	21	18	21
	SD	0.95	1.35	1.07	1.07	0.95	1.41	0.98	0.90	1.05	1.72
Small sized (10-50 employees)	Mean	4.11	3.78	3.44	3.22	3.89	3.89	4.11	3.44	3.38	3.44
	N	27	27	27	27	29	27	27	27	24	27
	SD	0.78	1.09	0.88	0.67	0.78	1.05	0.93	1.13	1.30	1.13
Medium sized (51-250 employees)	Mean	3.91	3.91	4.00	3.70	4.00	3.82	3.64	3.64	3.73	3.60
	N	33	33	33	30	27	33	33	33	33	30
	SD	1.22	0.83	0.45	0.95	1.12	0.75	0.81	1.03	1.10	1.51
Large (250 or more employees)	Mean	4.16	4.03	4.03	4.13	3.88	3.84	3.94	3.97	3.87	3.72
	N	93	96	96	93	96	96	63	93	90	96
	SD	0.90	1.03	1.03	0.92	1.07	1.17	1.15	1.11	1.04	0.81
Total	Mean	4.05	3.95	3.95	3.91	3.88	3.86	3.86	3.81	3.73	3.62
	N	174	177	177	171	171	177	176	176	165	174
	SD	0.94	1.02	0.94	0.95	1.00	1.09	1.03	1.07	1.08	1.11

Table 6-4: Size of organisation and H&S practices

	1*	2*	3*	4*	5*	6*	7*	8*	Number
Micro sized (1-9 employees)	12	9	6	6	0	3	0	6	21
	57.10%	42.90%	28.60%	28.60%	0.00%	14.30%	0.00%	28.60%	
Small sized (10-50 employees)	15	12	15	12	15	3	0	6	27
	55.60%	44.40%	55.60%	44.40%	55.60%	11.10%	0.00%	22.20%	
Medium sized (51-250 employees)	21	24	15	18	18	0	6	9	33
	63.60%	72.70%	45.50%	54.50%	54.50%	0.00%	18.20%	27.30%	
Large (250 or more employees)	75	72	66	63	66	18	33	45	96
	78.10%	75.00%	68.80%	65.60%	68.80%	18.80%	34.40%	46.90%	
Total	123	117	102	99	99	24	39	66	177
	69.49%	66.10%	57.63%	55.93%	55.93%	13.56%	22.03%	37.29%	

1* Construction site workers undertake induction training

2* There is due process in place to investigate all incidents reported

3* Maintain an on-site register to record any hazards reported

4* We analyse site safety hazards in pre-construction stage

5* We have designated project safety personnel to on-site issues

6* We have a regular training programme for our site staff

7* We have clearly defined safety KPI

8* We follow the "safety by design" process by analysing safety hazards

Size of organisation and perceived barriers to implementation of BIM

There does not appear to be large differences between respondents' attitudes toward factors considered responsible for H&S, based on the size of their organisation' but medium and large firms were more likely to identify "behavioural change" as a factor (see Table 6-5).

Table 6-5: Size of organisation and perceived barriers to implementation of BIM

Size of organisation		**Behavioural change**	**Education and training**	**Information exchange**	**Cost of implementation**	**Time required to train staff**	**Other**	**Total (N)**
Micro sized (1-9 employees)	Count	36	36	9	9	9	0	63
	%	57.10%	57.10%	14.30%	14.30%	14.30%	0.00%	
Small sized (10-50 employees)	Count	45	72	45	45	36	0	81
	%	55.60%	88.90%	55.60%	55.60%	44.40%	0.00%	
Medium sized (51-250 employees)	Count	81	99	72	72	54	0	99
	%	81.80%	100.00 %	72.70%	72.70%	54.50%	0.00%	
Large (250 or more employees)	Count	198	243	162	198	135	18	279
	%	71.00%	87.10%	58.10%	71.00%	48.40%	6.50%	
Total	Count	360	450	96	324	234	18	522
		68.9	86.2	55.17	62.06	44.82	3.4	

6.2.14 Nature of Business – Cross Tabulations

Cross tabulations were carried out in relation to the nature of the business (i.e. general contracting, designing, consulting, specialist subcontract or other) carried out by the respondent's firm, to examine whether attitudes or experience in relation to BIM vary according to the nature of the business.

Nature of business by H&S Practices Used

There were some differences in H&S practices, according to the nature of the business (see statements in Table 5-6). While a majority of respondents in every type of business said that they carry out induction training for construction workers, this figure is relatively low for specialist subcontractors (54.5%). Those in consulting were much less likely to say that due process is followed to investigate all reported incidents. General contractors were least likely to say that they analyse site safety hazards in pre-construction stages. Regular training for site staff and supervisors is not carried out at all by specialist subcontractors or others and only by a fairly small minority of all categories, including general contracting (21.7% say they do this regularly). Safety by design is much more likely to be used by those whose main business is design, general contracting or consulting (see Table 6-6).

Table 6-6: Nature of business by H&S practices

	1*	2*	3*	4*	5*	6*	7*	8*	Total
General contracting	54	42	36	30	33	15	12	27	69
	78.30%	60.90%	52.20%	43.50%	47.80%	21.70%	17.40%	39.10%	
Designing	24	30	27	21	24	6	18	12	39
	61.50%	76.90%	69.20%	53.80%	61.50%	15.40%	46.20%	46.20%	
Consulting	15	12	15	15	18	3	6	9	24
	62.50%	50.00%	62.50%	62.50%	75.00%	12.50%	25.00%	37.50%	
Specialist Subcontracting	18	24	21	24	18	0	3	9	33
	54.50%	72.70%	63.60%	72.70%	54.50%	0.00%	9.10%	27.30%	
Other	12	12	6	9	9	0	3	3	15
	80.00%	80.00%	40.00%	60.00%	60.00%	0.00%	20.00%	20.00%	
Total	123	120	105	99	72	24	42	66	180
	68.33%	66.67%	58.33%	55.00%	56.67%	13.33%	23.33%	36.67%	

1* Construction site workers undertake induction training

2* There is due process in place to investigate all incidents reported

3* Maintain an on-site register to record any hazards reported

4* We analyse site safety hazards in pre-construction stage

5* We have designated project safety personnel to manage on-site

6* We have a regular training programme for our site staff and subcontractors

7* We have clearly defined safety KPI

8* We follow the "safety by design" process by analysing safety hazards

Use and understanding of BIM by nature of business

Use of BIM is highest amongst those whose main business is designing (85%), followed by other (75%), specialist subcontracting (64%) and consulting (63%). General contracting businesses are the least likely to use BIM (a majority, 57%, do not do so) (see Figure 6-29).

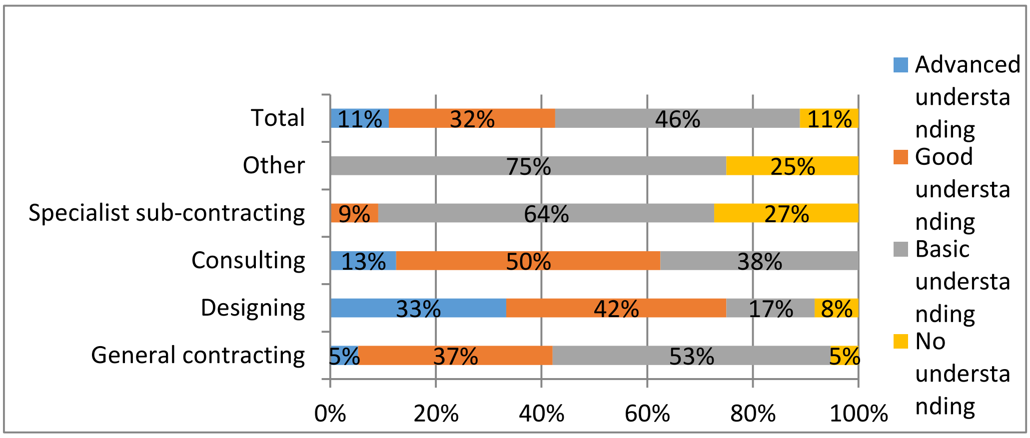

Figure 6-29:Nature of business by frequency of H&S issues

Respondents who said that designing was their main business are most likely to have a good or advanced understanding of BIM, followed by those whose main business is consulting and those whose main business is general contracting. Specialist subcontractors have the lowest level of understanding of BIM.

Factors considered responsible for H&S Issues by Nature of Business

Respondents were asked to rate a range of factors (from 1-5). Nearly all factors were rated as responsible for H&S issues by most types of business, with a relatively narrow range of means (see Table 6-7).

Table 6-7: Barriers to implementation of BIM by nature of business

		General contracting	Designing	Consulting	Specialist subcontracting	Other
Lack of effective communications	Mean	3.91	4.08	4.13	4	3.4
	SD	1.12	0.76	0.83	1.1	1.34
	Total N	69	39	24	33	15
Lack of effective site planning	Mean	3.91	3.92	3.88	3.82	4.2
	SD	1	0.76	0.99	1.08	1.3
	Total N	69	39	24	33	15
Poor implementation of H&S procedures	Mean	3.91	4.08	3.75	3.5	4.6
	SD	0.97	0.86	1.04	0.97	0.55
	Total N	69	39	24	33	15
Lack of regulations	Mean	3.26	3.92	4	3.7	4
	SD	1.21	1.04	1.07	1.06	0.71
	Total N	69	39	24	33	15
Human error	Mean	3.65	4	3.75	3.3	4
	SD	1.04	0.91	0.89	1.49	1
	Total N	69	39	24	33	15
Lack of H&S reporting culture	Mean	3.5	4.23	4.43	3.73	4.2
	SD	1.01	0.6	0.79	1.1	1.3
	Total N	69	39	24	33	15
Lack of consideration of H&S in planning and design stages	Mean	3.91	4.23	4.13	3.9	4.2
	SD	0.95	1.01	0.83	1.2	0.45
	Total N	69	39	24	33	15
Multiculture	Mean	3.7	3.92	4.13	3.8	3.8
	SD	1.18	1.04	0.83	1.14	0.84
	Total N	69	39	24	33	15
Low education	Mean	3.65	4.08	4	3.91	4
	SD	1.27	1.19	0.76	0.94	0.71
	Total N	69	39	24	33	15
Multilingual	Mean	3.52	4.17	3.88	3.91	4
	SD	1.27	0.94	0.99	0.83	0.71
	Total N	69	39	24	33	15

Consulting businesses are most likely to say that behaviour change is an important barrier to implementation of BIM (87.5%). A large majority of all group consider this important, with the exception of specialist subcontractors where just over half believe this is the case (see Table 6-8). Education and training is considered an important barrier to implementation by all types of business, but particularly consulting (100%), designing (92.3%) and specialist subcontracting (90%).

Table 6-8: Barriers to implementation of BIM by nature of business

	Behavioural change	**Education and training**	**Information exchange**	**Cost of implementation**	**Time required to train staff**	**Other**	**Total (N)**
General contracting	45	54	30	36	21	3	69
	65.20%	78.30%	43.50%	52.20%	30.40%	4.30%	
Designing	27	36	21	27	24	3	39
	69.20%	92.30%	53.80%	69.20%	61.50%	7.70%	
Consulting	21	24	18	18	12	0	24
	87.50%	100.00%	75.00%	75.00%	50.00%	0.00%	
Specialist subcontracting	18	30	24	21	18	3	33
	54.50%	90.90%	72.70%	63.60%	54.50%	9.10%	
Other	12	9	6	9	6	0	12
	100.00%	75.00%	50.00%	75.00%	50.00%	0.00%	
Total	123	153	99	111	81	9	177
	69.49%	86.44%	55.93%	62.71%	45.76%	5.08%	

6.2.15 Most important Factors for H&S

To conduct factor analysis, the one-tailed significance of Pearson correlation coefficients between all 18 of the factors was first assessed. As all factors seek to measure H&S in KSA construction industry, it would be expected that they would correlate with each other. Based on this assessment, the following factors were eliminated from the analysis for high significance values (>.450): DataMan, Knowledge, ChanceBeh, Equip, InfoExch, SafMeas, Cost and BetEnfor. The data indicate an issue of multicollinearity between InfoExch and RefSafMeet (correlated at 0.97), as well as between Knowledge and RegSafAudit (correlated at 0.99). For this reason, InfoExch has been excluded from the factor analysis. No variables need to be excluded based on the second instance of multicollinearity, as knowledge has already been excluded. This leaves the following variables for consideration in factor analysis: RegSageMeet, SafTrainProg, Proactive, GoodCom, HSIncidRep, SafLead, PerResp, Dvis and StakeCom.

Factor analysis, conducted in SPSS, first produced a Kaiser-Meyer-Olkin Measure of Sampling Adequacy of .771, which indicates a moderate pattern of correlation in the data and that this data set is appropriate for factor analysis. According to Kaiser (1974), values greater than .05 are acceptable for factor analysis, while values between 0.7 and 0.8 are "good". Moreover, the significance of Barlett's Test of Sphericity is highly significant ($p<.000$), which also indicates that this factor analysis is an appropriate test for factor analysis.

The results of the factor analysis (see Table 6-9) indicate that factor one explains 30.037% of the total variance. Factor analysis has been set up to produce the factor of most importance and, for this reason, only one factor is presented on the right side of the table, as having an eigenvalue greater than 1. This is presented in the screen plot in Figure 6-30. As the plot trails off after the first four factors, this indicates that the first four factors would have been retained for analysis if the settings had not been established to limit the output to the single most important factor.

Table 6-9: Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.407	30.037	30.037	5.407	30.037	30.037
2	3.248	18.047	48.084			
3	1.907	10.597	58.680			
4	1.120	6.223	64.903			
5	.873	4.847	69.750			
6	.831	4.619	74.370			
7	.723	4.015	78.384			
8	.663	3.684	82.069			
9	.634	3.522	85.590			
10	.496	2.757	88.348			
11	.467	2.592	90.939			
12	.341	1.896	92.836			
13	.318	1.764	94.600			
14	.296	1.642	96.241			
15	.236	1.313	97.555			
16	.177	.984	98.539			
17	.150	.832	99.371			
18	.113	.629	100.000			
Extraction Method: Principal Component Analysis						

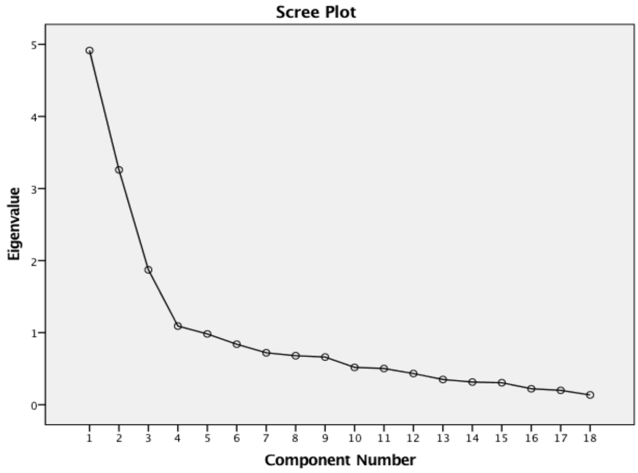

Figure 6-30: Factor analysis screen plot

The most significant factor is composed of the variables in Table 6-10. The table is set to show loadings less than 0.4. From these factors, common these are assessed to determine the similarities that contribute to the factor.

Table 6-10: Component matrix

	Component
	1
Proactive	.862
SafLead	.851
GoodCom	.831
HSIncidRep	.819
RegSafMeet	.800
RegSafAudit	.746
PerResp	.724
SafTrainProg	.722
Dvis	
Cost	
SafMeas	
Knowledge	
StakeCom	
Equip	
InfoExch	
BetEnfor	
DataMan	
ChangeBeh	
Extraction Method: Principal Component Analysis	
a. One component extracted	

6.2.16 OLS Regression Statistical Analysis

As the factor analysis has narrowed down the 18 factors to the eight more significant factors (i.e. those that are more representative of the perceptions of respondents in regard to H&S), these eight are now subject to further statistical analysis. The data were tested using the following regression models:

Regression Model 1:

HandSExp = β0 + β1 Proactive + β2 SafLead+ β3 GoodCom+ β4 HSIncidRep + β5 RegSafeMeet + β6 RegSafeAudit + β7 PerResp + β8 SafeTrainProg + β9 firmsize + β10SExpHandSIss +ε

Regression Model 2:

H&SFreq = β0 + β1 Proactive + β2 SafLead+ β3 GoodCom+ β4 HSIncidRep + β5 RegSafeMeet + β6 RegSafeAudit + β7 PerResp + β8 SafeTrainProg + β9 firmsize + β10SExpHandSIss + β11 HandSUse +ε

In the first model, the dependent variable is use of construction safety policies and practices, and the independent variables are the eight that comprise factor one in the factor analysis presented herein, controlling for firm size (micro, small, medium or large) and experience of H&S issues (binary).

In the second model, the dependent variable is the frequency of H&S issues; the independent variables are use of construction safety policies and practices, as well as the eight variables that comprise factor one in the factor analysis presented herein, controlling for firm size (micro, small, medium or large) and experience of H&S issues (binary).

These models were run in SPSS using the survey data. For the first model, the correlation between the observed and predicted values, R, is .511 and the R-squared is .261. The F-statistic for the model is 1.805 and the associated p-value is 0.93. This research has established alpha at 0.05. Therefore, the first model is not statistically significant. This is confirmed by the correlation table below, in which only one variable, proactive ($p \leq 0.05$), has a statistically significant impact on use of construction safety policies and practices (see Table 6-11).

Table 6-11: Coefficients

Coefficients[a]						
Model		**Unstandardised Coefficients**		**Standardised Coefficients**	**t**	**Sig.**
		B	**Std. Error**	**Beta**		
1	(Constant)	.364	.206		1.766	.084
	FirmSize	.006	.046	.021	.139	.890
	Proactive	.123	.054	.459	2.254	.029
	Saflead	-.003	.058	-.011	-.054	.958
	Goodcom	.088	.055	.321	1.592	.118
	Hsincrep	-.006	.058	-.024	-.104	.917
	Regsafemeet	-.014	.076	-.052	-.183	.856
	Regsafesaudit	-.027	.057	-.106	-.465	.644
	Perresp	-.041	.075	-.132	-.546	.587
	Safetrainprog	.017	.051	.059	.325	.747
a. Dependent Variable: HandSExp						

Similarly, the regression analysis for the second model cannot be concluded to be significant. For the second model, the correlation between the observed and predicted values, R, is .511 and the R-squared is .406. The F-statistic for the model is .807 and the associated p-value is 0.567. This research has established alpha at 0.05. Therefore, the second model is not statistically significant. This is confirmed by the correlation table below, in which only one variable, 'firmsize' ($p \leq 0.05$), has a statistically significant impact on use of construction safety policies and practices (see Table 6-12).

6.2.17 ANOVA Statistical Analysis

Although the two models used in regression analysis were not found to be statistically significance, in the second model, one variable—firm size—was concluded to be statistically significant. To assess further the role of firm size, analysis of variance (ANOVA) was used as a statistical model to determine the differences in responses among firms of different sizes. While the cross tabulations presented previously in this chapter are useful for providing descriptive statistics to compare firms by size, ANOVA is useful for applying a measure of statistical significance to the cross tabulations.

Table 6-12: Coefficients[a]

Coefficients[a]						
Model		**Unstandardised Coefficients**		**Standardised Coefficients**	**t**	**Sig.**
		B	**Std. Error**	**Beta**		
1	(Constant)	2.136	.680		3.142	.003
	FirmSize	.294	.144	.332	2.035	.048
	Proactive	-.074	.185	-.097	-.398	.692
	Saflead	.006	.181	.008	.034	.973
	Goodcom	.117	.176	.150	.667	.508
	Hsincrep	-.126	.181	-.176	-.699	.488
	Regsafemeet	.184	.237	.240	.774	.443
	Regsafesaudit	.158	.179	.220	.887	.380
	Perresp	-.401	.233	-.453	-1.725	.092
	Safetrainprog	-.083	.159	-.103	-.523	.604
	HandSExp	.117	.502	.038	.233	.817
a. Dependent Variable: HandSFreq						

Using an alpha of 0.05, the results indicate that firm size is statistically significant in the differences for two variables: 1) better communication devices for efficient information storage (p=.038); 2) H&S incident reporting culture (p=.018). Specifically, the Tukey post-hoc test results presented in Table 6-13 indicate that there is a statistically significant difference between the means for micro-sized and large-sized firms.

Table 6-13: Factor analysis

Tukey HSD							
Dependent Variable	(I) FirmSize	(J) FirmSize	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
HandSExp	1	2	-.063	.175	.983	-.53	.40
		3	-.195	.168	.653	-.64	.25
		4	-.192	.145	.550	-.58	.19
	2	1	.063	.175	.983	-.40	.53
		3	-.131	.156	.834	-.54	.28
		4	-.128	.131	.760	-.48	.22
	3	1	.195	.168	.653	-.25	.64
		2	.131	.156	.834	-.28	.54
		4	.003	.121	1.000	-.32	.32
	4	1	.192	.145	.550	-.19	.58
		2	.128	.131	.760	-.22	.48
		3	-.003	.121	1.000	-.32	.32
HandSFreq	1	2	-.714	.525	.530	-2.11	.68
		3	-.558	.475	.645	-1.82	.70
		4	-.723	.410	.302	-1.81	.36
	2	1	.714	.525	.530	-.68	2.11
		3	.156	.475	.988	-1.10	1.42
		4	-.009	.410	1.000	-1.10	1.08
	3	1	.558	.475	.645	-.70	1.82
		2	-.156	.475	.988	-1.42	1.10
		4	-.165	.344	.963	-1.08	.75
	4	1	.723	.410	.302	-.36	1.81
		2	.009	.410	1.000	-1.08	1.10
		3	.165	.344	.963	-.75	1.08
proactive	1	2	-.651	.603	.703	-2.25	.95
		3	-1.065	.578	.265	-2.60	.47
		4	-1.241	.499	.073	-2.56	.08

	2	1	.651	.603	.703	-.95	2.25
		3	-.414	.538	.867	-1.84	1.01
		4	-.590	.451	.562	-1.79	.61
	3	1	1.065	.578	.265	-.47	2.60
		2	.414	.538	.867	-1.01	1.84
		4	-.176	.418	.975	-1.28	.93
	4	1	1.241	.499	.073	-.08	2.56
		2	.590	.451	.562	-.61	1.79
		3	.176	.418	.975	-.93	1.28
Saflead	1	2	-.444	.588	.874	-2.00	1.11
		3	-.636	.565	.674	-2.13	.86
		4	-1.156	.487	.094	-2.45	.13
	2	1	.444	.588	.874	-1.11	2.00
		3	-.192	.525	.983	-1.58	1.20
		4	-.712	.441	.378	-1.88	.46
	3	1	.636	.565	.674	-.86	2.13
		2	.192	.525	.983	-1.20	1.58
		4	-.520	.408	.583	-1.60	.56
	4	1	1.156	.487	.094	-.13	2.45
		2	.712	.441	.378	-.46	1.88
		3	.520	.408	.583	-.56	1.60
goodcom	1	2	-.619	.603	.735	-2.22	.98
		3	-.740	.579	.580	-2.27	.79
		4	-1.379*	.500	.038	-2.70	-.06
	2	1	.619	.603	.735	-.98	2.22
		3	-.121	.538	.996	-1.55	1.30
		4	-.760	.452	.342	-1.96	.44
	3	1	.740	.579	.580	-.79	2.27
		2	.121	.538	.996	-1.30	1.55
		4	-.639	.419	.429	-1.75	.47
	4	1	1.379*	.500	.038	.06	2.70
		2	.760	.452	.342	-.44	1.96

		3	.639	.419	.429	-.47	1.75
hsincrep	1	2	-.839	.660	.584	-2.59	.91
		3	-1.260	.616	.185	-2.89	.37
		4	-1.621*	.532	.018	-3.03	-.21
	2	1	.839	.660	.584	-.91	2.59
		3	-.420	.592	.893	-1.99	1.15
		4	-.781	.504	.415	-2.12	.55
	3	1	1.260	.616	.185	-.37	2.89
		2	.420	.592	.893	-1.15	1.99
		4	-.361	.446	.850	-1.54	.82
	4	1	1.621*	.532	.018	.21	3.03
		2	.781	.504	.415	-.55	2.12
		3	.361	.446	.850	-.82	1.54
Regsafemeet	1	2	-.607	.648	.785	-2.33	1.11
		3	-.675	.606	.682	-2.28	.93
		4	-.763	.523	.468	-2.15	.62
	2	1	.607	.648	.785	-1.11	2.33
		3	-.068	.582	.999	-1.61	1.47
		4	-.156	.495	.989	-1.47	1.16
	3	1	.675	.606	.682	-.93	2.28
		2	.068	.582	.999	-1.47	1.61
		4	-.088	.438	.997	-1.25	1.07
	4	1	.763	.523	.468	-.62	2.15
		2	.156	.495	.989	-1.16	1.47
		3	.088	.438	.997	-1.07	1.25
Regsafesaudit	1	2	-.804	.665	.625	-2.57	.96
		3	-1.156	.622	.258	-2.80	.49
		4	-1.210	.536	.122	-2.63	.21
	2	1	.804	.665	.625	-.96	2.57
		3	-.352	.597	.935	-1.94	1.23
		4	-.406	.508	.854	-1.75	.94
	3	1	1.156	.622	.258	-.49	2.80

		2	.352	.597	.935	-1.23	1.94
		4	-.054	.449	.999	-1.25	1.14
	4	1	1.210	.536	.122	-.21	2.63
		2	.406	.508	.854	-.94	1.75
		3	.054	.449	.999	-1.14	1.25
Perresp	1	2	-.746	.515	.474	-2.11	.62
		3	-.403	.494	.847	-1.71	.91
		4	-1.045	.426	.079	-2.17	.08
	2	1	.746	.515	.474	-.62	2.11
		3	.343	.459	.877	-.87	1.56
		4	-.299	.385	.865	-1.32	.72
	3	1	.403	.494	.847	-.91	1.71
		2	-.343	.459	.877	-1.56	.87
		4	-.642	.357	.285	-1.59	.30
	4	1	1.045	.426	.079	-.08	2.17
		2	.299	.385	.865	-.72	1.32
		3	.642	.357	.285	-.30	1.59
Safetrainprog	1	2	-.238	.588	.977	-1.80	1.32
		3	-.171	.575	.991	-1.70	1.35
		4	-.696	.487	.487	-1.99	.60
	2	1	.238	.588	.977	-1.32	1.80
		3	.067	.536	.999	-1.36	1.49
		4	-.458	.441	.727	-1.63	.71
	3	1	.171	.575	.991	-1.35	1.70
		2	-.067	.536	.999	-1.49	1.36
		4	-.525	.423	.604	-1.65	.60
	4	1	.696	.487	.487	-.60	1.99
		2	.458	.441	.727	-.71	1.63
		3	.525	.423	.604	-.60	1.65
*. Mean difference is significant at the 0.05 level							

For good communication, there is a mean difference between micro sized firms (indicated by “1” in the second and third column of the above table) and large sized firms (indicated by “4” in the table) of -1.379 (p=.038). This indicates that micro-sized firms have statistically significant better communication devices than do large-sized firms. Moreover, there is a mean difference between micro-sized and large-sized firms of -1.621 (p=.018) for incident reporting culture. This also indicates that micro-sized firms have a statistically significant better incident reporting culture than do large-sized firms. For the remainder of the variables, no statistically significant differences are concluded based on firm size.

6.3 Qualitative Data Analysis

6.3.1 Introduction

The quantitative data collected and analysed, used a structured survey instrument that was developed by the researcher for the purpose of statistical analysis. While this is a useful means of answering research questions, by producing numerical data that can be analysed and presented in visual format, as referred to in the Methodology section, there is often a further dimension added by collecting data through interviews and then analysing it. This is the strength of mixed methodology, in allowing some triangulation, to add validation to the data analysed quantitatively and to support reliability.

Moreover, although interviews in this case were semi-structured, the answers were verbal and open-ended, allowing for more explanation and individuation in the data. The data, as described in Chapter 3, were collected then examined for recurring themes that would make a more rigorous and detailed contribution to answering the research questions, one that might allow a deeper insight into the attitudes and beliefs that underlie behaviours.

This section presents the seven themes that emerged from the interview data, including supporting quotes from interviewees, followed by a conceptual model of the relationship between these themes. The following themes were identified through thematic analysis of the interview data, with BIM having a section of questions in the interviews designed to elicit the data needed for this study:

- Regulation
- The migrant workforce – culture and communication
- Training
- Understanding of H&S matters

- Provision of safety equipment
- Environmental challenges
- BIM

Table 6-14, with data coded to each of these themes, provides demographic information on the participants, including age, position, expertise, educational attainment, area of work and years of experience. These data are used to provide contextual information to the interview data. To this effect, the participant ID provided in the first column of the table is included with quotes presented as part of this data analysis.

6.3.2 Regulation

There are many different beliefs and attitudes expressed by the participants, but what emerges is that it is difficult for them to decide on where exactly to place the blame for the lack of regulation. Many have decided that it is the government that is at fault:

> *The biggest challenge in implementing HEALTH AND SAFETY is compliance with the international standards. The reason is that there is no clear standard with which you can carry out your assessment*. IG

"International standards" are also emphasised by IE, while IB calls them "rules which have been modelled from other countries", although IJ explains that regulation is inadequate if compared to the UK, but that in KSA the standards are "under development". Other participants also take up the issue of clarity. IA calls the rules "unclear" and II also states that the regulations are "not clear"; IF goes further, claiming that lack of H&S clarity in governmental standards, regulation and enforcement leads to a situation where "the company owner and the workforce feel as if there is no law to safeguard their lives".

Table 6-14: Participant information

Participant	Age	Position	Expertise	Level of education	Area of work	Years of experience
IA	39	Project manager	Construction management	Master	Public sector	12
IB	35	Lecturer	Architecture	PhD	University	5
IC	33	Manager and university lecturer	Architecture and management	PhD	Public sector	6
ID	33	Head of engineering	Engineering	Masters	Civil service	10
IE	34	Supervisor of public projects	Engineering	Master	Civil service	8
IF	45	Project manager, international company (Chinese)	Engineering	Bachelor	Private sector.	19
IG	44	Civil defence captain	Engineering	Master	Public sector.	20
IH	52	Site manager	Engineering	Bachelor	Private sector	25
II	31	Contractor	Architecture	PhD	Public sector	6
IJ	29	Contractor	Architecture management	Master	Public sector	5

ID and others believe that the government should insist on making H&S issues contractual:

> *The governmental bodies do not include the conditions and obligations concerning HEALTH AND SAFETY as mandatory parts of a contract. Even if it is included, there is no commitment for its implementation.* ID

IB agrees, saying that "for acquiring permission for construction, a set of conditions should be met" and IA supports this suggestion:

> *(There should be) adherence by the workforce and anyone else that works on the site to all the HEALTH AND SAFETY rules and regulation. This obligation should be registered and clarified in the contract with them. Also there should be no negligence about it.* IB

Many participants approach the issue from the sanctions perspective, rather than suggesting a contractual clause that would be enforced before construction began. ID proposes “heavy fines” for anyone failing to abide by whatever regulation there might be. IE also supports the “application of fines”, while IB, in addition to advocating fines, appears to believe that sanctions should involve cancellation of insurance:

> *I suggest in order that health and safety regulations be observed, a third party be responsible for supervising the workers … They warn the workers who are negligent towards safety regulations and if this issue continues, they would cancel their insurance. My suggestion is that, if an accident happens to the worker, the company should bear the responsibility and the company should pay the insurance. In this way, the company will be forced to supervise its workforce on this issue.* IB

However, some participants seem to suggest that failure to abide by H&S regulations, however inadequate and not enforced, has other outcomes for construction companies, some of which may impact the company itself or the build that is taking place. IF draws attention to the damage that H&S failures can cause:

> *When a significant accident occurs, the police, civil defence forces and medical teams swarm in, resulting in the shut-down of the operation. This in turn will delay the date of the delivery, resulting in extra expenses. Furthermore, it hinders our credit and the company’s commitment to its contracts.* IF

The “market forces” argument is also supported by IG, who, without producing evidence, claims that “observation of the rules and regulations lowers the expenses”; although these practical or pragmatic observations are not taken up by others, there may be some validity to his argument.

Further, while claims made on this subject may come from one participant only, this may be a specific understanding of the issue given from a personal standpoint. Hence, it can be contested, as it is only a personal view with no support. However, it is important to include these comments in the analysis, as they may offer alternative views in this examination of perspectives on H&S regulation in KSA from an experiential although unsupported viewpoint. For instance, ID suggests that adherence to regulations may be less stringent in contractors in public construction than in private companies:

> *The section under government control; here, even if the issue of HEALTH AND SAFETY is mentioned in the contract – it is totally ignored. The private sector here, in contrast to the governmental section – HEALTH AND SAFETY regulations are adhered to much more, although it is far from acceptable.* ID

There is no evidence to support this judgment and none is offered; therefore, it must remain conjecture. Another individual claim can be better explained as possibly cultural. IH, a foreign contractor working in a foreign company, appears to have adopted the company's collectivist practices in the views and solutions he presents. The company's view appears to be that in the case of a safety infringement by a member of the workforce, the following procedure is to be adopted:

> *The most important issue to ensure the implementation of H&S is to compile a weekly report in regard to each of the workers. This report is an assessment of the worker's compliance with the safety regulations. The report will give marks from 1 to 10 and if a worker obtains 6 he will be called for a disciplinary meeting; and if this continues, part of his wages will be deducted as a fine.* IF

The personal contribution to a collectivist company is a cultural issue – that each member of the workforce is responsible for their actions and, therefore, for the success of the project.

6.3.3 Migrant Workforce

It is unsurprising that "migrant workforce" should emerge as one of the major themes because there were several questions in the semi-structured interview schedule that specifically asked about this subject. However, some of the responses were very interesting and attitudes to the overwhelmingly migrant workforce were, in general, negative. Participant IA describes the composition of the workforce in his construction company:

> *Saudi, Yemeni, Egyptian, Syrian, Jordanian, Palestinian, Sudanese, Malian, Ethiopian, Pakistani, Bengali, Indian, Turkish and Chinese.* IA

The challenges of the migrant workforce are said to fall into two categories, the problems of communication and those created by different cultures. As far as language is concerned, some of the interview responses are difficult to interpret. The following series of questions and answers appear in the interview with IA:

How many formal languages are used in within the organisation?

> *The official language in our transactions and communications is Arabic.* IA

Are there any people in your workforce that are not fluent in Arabic?

> *Yes, there are people who can't speak Arabic.* IA

IA does not say what means had been put in place to accommodate those who could not speak Arabic understand the instructions they might be given in what, to them, would be a foreign language. IG points out that communication difficulties result in a workforce that "don't understand all the warning signs, safety procedures and the regulations". And IJ notes:

> *Yes, some of the labour force don't follow instruction on construction sites because they misunderstand verbal and written site instructions. It's a lack of communication between them and us*. IJ

However, other participants refer to solutions they have found to the communication problem. ID and IF had come up with the same idea, to divide the workforce into groups who share a common language. ID also employs supervisors who can also act as interpreters for these different groups, while IF notes:

> *Their supervisor should be able to speak the group's language in addition to English and Arabic.* IF

The language barrier may also come between the workforce and supervisors, causing relationship difficulties. According to ID:

> *Language plays an important role because the worker is left in the dark about what is required from him. He cannot speak Arabic and his English is weak. More so, even in some cases the supervisors, engineers and directors face the same problem. Therefore, relationships between them become difficult and they have to resort to the language of signs and gestures to communicate with each other.* ID

This problem is not evident in all companies, as IH explains: "As we are a Chinese company, most of our workers come from China and countries where they speak English". The nature of many global companies is similar and IH said that his company had been operational in KSA for very many years and generally carries out projects in countries outside China.

Apart from written and verbal communication challenges, many participants mention a cultural difference in members of the workforce. IB observes:

> *The variety of cultures and languages has an enormous aftereffect in the construction sector. In KSA, workers come from different countries and their cultures differ greatly; and as a result, cooperation between them is very low.* IB

ID suggests that cultural difficulties are emphasised because there is a general low level of education in the diverse groups and "for this reason, they would face many difficulties between themselves". lH also refers to this lack of cooperation between the groups themselves: "Unfortunately, cooperation between them is poor and this issue results in the increase of accident rates". And IB is more specific on the issue of cultural difficulties and the matter of H&S:

> *The main challenge that we face in implementing safety rules is the divergence of the workers' languages and their lack of knowledge about the importance of health. This problem is exacerbated by the fact that the majority of the workers come from poor Asian countries where health and safety is of no importance. Therefore, the workforce from these countries has no obligation towards health and safety rules.* IB

According to site manager IH, one of the companies has made a decision that could perhaps solve the problem of communicating with a migrant workforce that makes up 85% of construction site workers. The company is Chinese, but it embodies what is meant by globalisation in that it operates internationally. Where companies operate in this way, there is often said to be a positive outcome that is referred to by participant IC: "If managed properly, having a multicultural/multilingual workforce would result in knowledge transfer to the Saudi context". IC is an academic and is emphasising the academic argument that knowledge from one culture can by shared by others in multinational companies; in KSA, this may result in an enhancement of skills, as more advanced and developed technology can be transferred in this way. It is, therefore, interesting to record what IH observes regarding his company's solution to the cultural and communication issues evident in this migrant workforce:

> *Since we are an international company and engaged in different countries, it has been our policy to lower the variety of nationalities in our workforce. By this policy, we have decreased the negative impacts created by the diversity of languages and cultures causing discord between the workers.* IH

This attitude appears to defy the assumption that globalisation operates almost solely on knowledge transfer. Perhaps if the migrant workforce were capable of sharing superior knowledge in an industry in which they specialise, the issue of knowledge transfer might be relevant. Interestingly, too, the behaviours of IH's company seem to reflect, in some ways, the 'Saudisation' policy adopted by KSA through limiting the nationality of its workforce to assist its operating strategies. Where there has been a need for a migrant workforce, it may be more useful to try to recruit from KSA population. This issue is further explored in the discussion chapter.

6.3.4 Training in H&S

The interview question answered to the third level of importance was training. Although this lies at the heart of all H&S practice in developed countries, it is the importance of training in H&S issues. Therefore, it is interesting to explore whether participants feel that there is sufficient training offered in this crucial aspect of KSA construction industry. Generally speaking, all participants recognise the importance of training, although most assume that training on H&S to be carried out by the workforce. As IH says, the issue here is:

> *[Accidents are] very high this year and all of the victims were from countries that I mentioned Therefore, we need to elevate the level of their knowledge by implementing training courses so that they learn to prioritise HEALTH AND SAFETY, enabling them to save their own lives in the workplace.* IH

Others appear to support this perspective. Yet, IE, in response to the question "Do you train your workers in health and safety?" replied "no". This may have been because of a misunderstanding about the specifics of the question, given that IE is a civil defence captain and not someone with hands-on experience of a construction site, but there are several examples of breaches or carelessness in training the entire workforce to be aware of H&S issues. IA is clear that every member of the workforce should be trained: "[What is important is] educating all the workforces and everyone else connected with the work on the site on the matter of health and safety". IB agrees and is specific in stating the importance of the training agenda reaching all levels of the workforce, but especially the foremen and on-site managers (supervisors), whom he classifies as those who "control the workforce":

> *The important point is that the supervisor should be competent in this responsibility and should have the necessary skill and ability. For this very reason, it is paramount that tutorial courses be held to increase the level of their competence, enabling them to control the workforce.* IB

The problem here is that few of the respondents are willing to state who are regarded as the workforce and who might be thought of as leaders. Engineers, for example, may be thought of as those sufficiently educated and experienced to lead others, but ID, an engineer in the civil service, claims:

> *In the circle of engineers, there is no understanding about health and safety. Also, there have not been any educational courses conducted in this field. I am not the first person who has no knowledge of the significance of health and safety and has not received any training about it. More so, I have not come across any of the engineers or staff who mentioned this issue in building construction.*
>
> *No, I have not passed any training course and I think this is something which is unknown in the government sector.*
>
> *…. courses should be conducted for all staff, including the workers, engineers and the clerical personnel.* ID

It may be suggested here that engineers who perhaps should lead others towards understanding of and compliance with basic H&S requirements may not be in a position to do so, as they are not, themselves, trained. This could, of course, be a totally individual understanding and experience with no possibility of generalisation in this survey. This often occurs in qualitative data analysis, especially in those with a small sample size like this. Moreover, IF claims that, contrary to ID's experience, "the engineers working for our company have passed health and safety courses".

In IF's company, there is a H&S officer, a qualified engineer who has attended and passed H&S courses. This officer guides the entire workforce in H&S matters. Among his responsibilities are organising regular explanatory courses, printing leaflets and putting up signage. His role is to ensure that all workers are aware of and abide by the rules and regulations that may be set out and to raise awareness of H&S.

> *At the outset of each project, a meeting is held with all the individuals involved in the site. In this meeting, observance of health and safety regulations is emphasised and the safety officer is asked to brief them on these matters. In addition, a course is held for the workforce about actions which should be undertaken in an emergency situation at the site*. IF

In the light of this statement regarding emergency situations, it is interesting to compare the management in his company with the regulatory requirements as claimed by IG who, as a captain in the civil defence, is responsible for guidance on behaviours in emergency situations:

> *Yes, there are special training courses in relation to evacuation procedures during fire or accidents. But these are only for universities, hospitals and ministries.* IG

There does appear to be a degree of confusion regarding training and the role played by H&S officers in construction companies, if one is employed at all. There is also some confusion about the degree of qualification necessary to work in this role. IH claims that there are engineers who have fake educational qualifications and "therefore they have no experience at all in health and safety". Yet, IG appears to believe that there need be little educational qualification held for the role of H&S officer:

> *Yes, we allocate a person responsible for health and safety on project sites. But we do not specify a certain level of education for him. The one and only important matter for us is that he should be capable of executing his duties.* IG

This seems to be a denial of his stated belief about the crucial importance of H&S issues. That someone with limited qualification could take on the role suggests that contractors may not take matters as seriously as they claim they do with regard to what IC calls "disseminating the culture of safety".

The question of who might be held accountable for safety breaches and training, and the reasons for the neglect that might persist in some construction companies is a topic that IF seems to be particularly concerned with:

> *In my opinion, the first body responsible for all accidents is the high executive committee of the company, which is mainly concerned about the profits rather than the health and safety of the workforce. They are looking for cheap, unqualified workers and never organise training courses to teach them how to safeguard their lives*. IF

He clearly has views on the lack of importance given to H&S issues and also points to a reason for this – that unqualified labour is available and cheap – and, he implies, more attention should be paid to the lives of those so employed. He is not alone in this summary of why H&S matters are often ignored. In reply to the question "What are the major challenges in enforcing health and safety standards in construction sites in KSA?", II gives a blunt answer: "Cost issues related to training sessions for the new workforce".

The next section takes up an examination of an emergent theme that is closely related to this one. It is a general lack of knowledge of and lack of interest in understanding H&S matters.

6.3.5 Lack of Interest in and Understanding of H&S

One of the most notable aspects of attitudes to H&S is summed up by IA: "Our engineers do understand H&S but unfortunately they do not comprehend its real importance". This is the crucial point and one that is repeated in different ways throughout these interviews by different participants. The lack of understanding of the real necessity of these matters is evident throughout several of the other themes, which is why, here, any further issues can be seen. Of all the interviewees, ID, a civil servant, is the most passionate about protecting the labour force:

> *I repeat, the main challenge for all of us is ignorance towards the importance of safeguarding the lives of the workers in this sector*. ID

ID obviously expresses a belief in the importance of human life and also the necessity for the industry to take over full responsibility for the welfare of its workers, many of whom may be unsure about how to ensure their own safety and may put themselves in dangerous situations without being fully aware of the possible consequences. IF draws attention to the youngest of the migrant workers, those between the ages of 18 and 22, who have little knowledge of safety matters He says that they "try to accomplish the job without paying attention to using safety equipment". Rather than drawing attention to the age of these workers, IG, while supporting the beliefs of IF, also cites the lack of experience in many of the migrant workers:

> *Also, some of the workers employed don't even know the ABC of safety issues. They learn as they start work on the site; therefore, they have no idea of how to safeguard their own health.* IG

IB is also in agreement about the lack of understanding amongst the workforce, noting that the majority of workers come from poor Asian countries where H&S is of no importance. This, then, he is saying, may be a cultural issue, as has been pointed out by other interviewees in previous sections of this analysis.

However, these three participants here focus on the workers themselves. ID and others also focus on the arguably lax standards on construction sites in the public sector, as this is where he is employed:

> *Regrettably, on the sites and projects which I supervised the number exceeds 30 and I didn't see any health and safety officers there … During the 10 years at this job, I have not witnessed any consideration by the director of the project or the workers on the issue of health and safety*. ID

Considering ID's position, this is a very damning statement about responsibility of care on the sites he was in charge of; therefore, one may assume that this observation may possibly be true of other construction sites in KSA.

The question, however, is – what do participants believe or imagine might be the reason for the ignorance and neglect of H&S matters? IE believes that "senior management as they look to profits more than the consideration of maintaining the safety of workers" is the problem, that the need for profit means that, on many sites, costs will be cut in ways that might damage workers' safety. IG agrees that this is a major issue: "Observance of H&S standards and not thinking of just earning money in expense of quality should be practised".

Yet, IG also points out the short sightedness of this attitude:

> *Many of the managers think of health and safety as something trivial; this leads to many big losses in future*. IG

This is perhaps the crux of this matter. If there is a careless attitude to the H&S of the workforce, as argued in previous sections, particularly by IF and IH, both of whom work in private companies, short-term savings on something as essential as H&S can lead to workplace accidents that can cause delays and impact on reputation and profit. To ensure that the workforce remains safe, it is important, the interviewees say, to raise awareness of H&S matters as perhaps a practical necessity. In the next section, participants offer their views on site safety, safety equipment and its life-saving nature. It is another emergent theme.

6.3.6 Safety Equipment, Signage and Precautions

IB, who cites a much-publicised tragic accident that occurred in recent months, most forcibly creates the discussion on this subject:

> *We have had many examples of neglect concerning the safety regulations. One example was the death of 40 workers in the tower in front of the shrine in Mecca during the month of Ramadan. All the workers died in the ventilation part of the building where only a piece of wood was put for the workers to pass over. As a result, they fell to their death.* IB

The accident he refers to occurred at one of the main building sites of one of the biggest and most successful construction companies in the Middle East, but ID explains that "naturally, the larger the project, the higher the number of workers involved, resulting in more accidents". It is a very discouraging picture that does little to suggest that accidents are not a routine and expected part of the construction industry.

IA speaks about the basic issues of what should occur in order to make a construction site safe for those who work on it; therefore, the solutions to workplace accidents are known but perhaps not implemented:

> *There should be the installation of pillars and preventive stands to protect the workforce from falling stones or piles of earth. Contractors should make sure of*

> *the presence of skilled technical staff for installation of cranes and lift. The role of management in keeping the work area nice and tidy is very important … briefing all personnel on the warning and educational signs put up in the workplace.* IA

This comment underlines what was discussed in the previous section, where it became clear that although there is some ignorance of the nature of a safety culture, a more important issue perhaps is the failure to comply, even when safety rules are known. IC claims that some of the workers, themselves, ignore the rules of safety, preferring to go about their tasks in their own way: “Some site workers and sometimes engineers ignore some of the essential safety precautions, as they consider their tasks as routine work”. IB says that it is not unusual for workers to be on the site without boots and hard hats. an observation also noted by IF. IB continues:

> *Also, we witness that the workers don’t make use of safety belts when working at height. In addition, the workers secure themselves using primitive facilities.* IB

The matter of workers not adhering to safety standards may be, as discussed in the literature review, a cultural issue within communities where fatalistic attitudes may predominate.

6.3.7 Environment

As has been discussed previously, the working conditions in KSA can be as dangerous as a poorly managed construction site. The issue here may be health rather than safety; and although this challenge to H&S is the least mentioned in the interviews, those who mention it try to draw attention to how serious this concern is. IH raises most of the important issues:

> *Also, the other important issue which affects the health of the workers is the weather condition of the country. The companies ask the workers to work at temperatures above 50 degrees Centigrade, despite the fact that the government has prohibited work at these temperatures. Regrettably, the companies force their workforce to do so. The challenge that our company faces is to adapt our workers to the climate here in Saudi Arabia. The high temperature is the cause of many serious accidents because our workers are not used to working in such a climate. Wearing a special suit, safety hat and boots in temperatures above 50 degrees, up to 60 sometimes, is very demanding.* IH

IH is part of a Chinese international company and many of its workers could be from the colder northern regions of China and find it difficult to acclimatise to the Saudi heat. But the climate is a major problem for building sites. If, during several months of the year, temperatures are so high and safety equipment so heavy, it is not only irresponsible for companies to expect a workforce to operate in these conditions, when the regulations state that this should not happen, but is likely to cost lives, as IH says. It should also be noted that working in temperatures of this kind during Ramadan, when the intake of food and, particularly, drink is limited to the hours of darkness, may play some part in endangering health on construction sites.

IA is also very concerned at the insistence that work on construction sites continues in the most adverse conditions:

> *The other important factor is the high temperatures and sandstorms in the area which greatly affect the health of the workforce. [There should be] prevention of work during unfavourable weather conditions, such as high temperatures or high winds and sandstorms.* IA

The final section focuses on a part of the interview that was specific and direct. It concerns the use of BIM.

6.3.8 BIM

As several questions were asked on this topic, it had a degree of response, although generally few people had used the system that replicates in 3D, 4D or even 5D the progress of the design of a building (see Chapter 3). Sadly, none of these interviewees had used BIM, but several were very enthusiastic about its possibilities as a technological system that could enable designers, architects, engineers and all the workforce to view the construction stages up to completion and see the build in a time and costs format. The implications for such a programme are very important for the issues of H&S on a construction site.

> *I think we could use augmented realty to present issues within H&S for workers. That could help them to understand the situation of the location. The link between health and safety and BIM can be developed further to cover this issue. BIM can be developed further to cover this issue. By viewing the model in a 3D*

> *environment, workers can understand the situation of health and safety and what they should do in case of emergency.* IB

Augmented or virtual reality is a major tool for those who have a language barrier and cannot easily visualise the layout of the site or their role and routes. This can, therefore, perhaps contribute to the solution of one of KSA's most serious challenges in attempting to set up a construction industry to supply the country with an infrastructure, but an industry manned by a migrant workforce with a variety of languages and understandings. IB has seen perhaps the biggest contribution offered by BIM to developing nations in their pursuit of H&S in the construction industry.

Not all interviewees were so positive about the advantages to H&S that BIM might give. Some had not heard of it. IC had heard of it but had no interest, even claiming that he could not see the need for BIM in site induction for migrant workers who had language problems. IB, despite his understanding of augmented reality and its use in induction, was very specific about BIM and the KSA construction industry, giving a response that was totally oppositional to what many who answered the questionnaire had said. This matter is explored in the discussion section:

> *Unfortunately, we did not intend to utilise BIM for health and safety. In fact, we use Revit for architecture drawings only. Then we export the file from Revit to AutoCAD. The concept of BIM has not been fully implemented within the first stage of the design process yet … and, as far as I know, none of the construction companies in KSA have used it within the construction phase*. IB

Evidence from the interviews is that BIM may have been something the participants know about and some are positive about what they hope it might do for their companies. IA says: "I don't think we can use it now, as it needs educational provisions and facilities that may be costly", while IC states: "We do not intend to use BIM for health and safety". ID agrees with IB that the use of BIM was limited in KSA: "I have not worked with it and during my work experience in this sector I have not come across it". IF also notes that his company does not use BIM, although it may be used some time in the future: "I believe that implementing this system will improve health and safety in our company and in the work place". IH, too, claims that his company might use BIM "soon":

So far it has not been used but we will consider it seriously, since it has a direct impact on progress of the job, reduction of time and lowering the number of mistakes. It will also connect the company to a system that would make the execution of the job easier and ensure the progress of the project. IH

In general, IH shows considerable enthusiasm for and detailed knowledge of BIM. However, in summary, none of these participants have ever used BIM and few appear to have a real understanding of its use and potential.

These observations conclude the results section of this study. It now continues to the discussion section, after which suggestions are put forward for creating a H&S framework.

6.3.9 Relationship between Qualitative Themes

Although the seven themes thus far have been presented as independent concepts relating to H&S in the construction industry in KSA, one must acknowledge that they are intimately intertwined. To this effect, the concept map in Figure 6-31 has been developed to present the relationships between the seven themes (shown in yellow). The arrows are used to indicate the causal direction. For instance, that from 'lack of training' to 'not using BIM' indicates that the lack of training of the interviewees is one reason they are not using BIM for H&S issues. Note that the lack of government regulation is demonstrated to be the likely cause of many of the issues that emerged: lack of training, not using BIM, lack of understanding and poorly managed conditions.

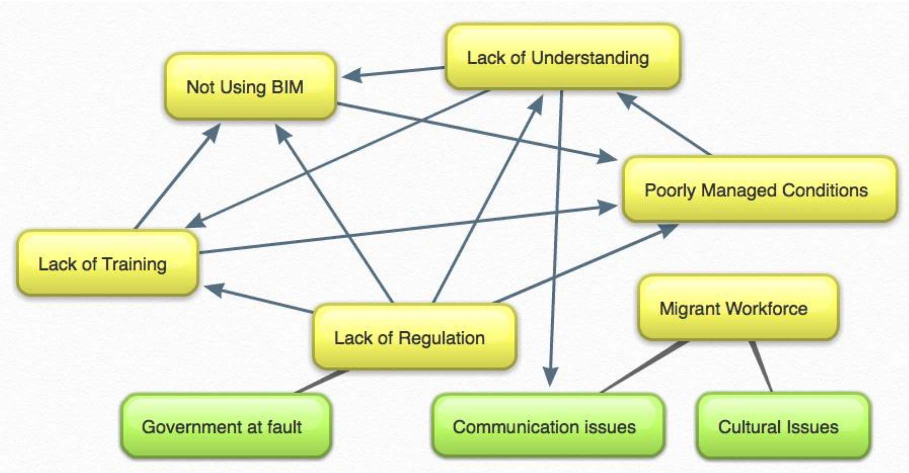

Figure 6-31:Relationship between qualitative themes

6.4 Summary of Findings

6.4.1 Summary of Quantitative Findings

The aim of Section 6.2 was to carry out a quantitative analysis of the data collected from the field study, with a view to buttressing the aim of the study. In this section, a chronicle analysis has been carried out which has examined the use of BIM in the management of H&S in KSA construction sector and the impact of BIM on H&S in its public construction sector. The section has also examined the level of knowledge and usage of both BIM and H&S policies and has highlighted the factors that affect effective implementation of H&S policies.

The survey data reveal broad H&S trends in KSA public sector construction industry. The data indicate that 85% of respondents have experienced H&S issues in their projects. The most common of these hazards are slips, trips and falls (63.79%), heat exhaustion (56.90%) and hazardous substances (51.72%). However, the hazard with lowest frequency—fire outbreak (22.41%)—still occurs in almost a quarter of construction sites. Yet, less than one-third of respondents reported to have policies and practices fully integrated and widely observed (31.67%), and an additional 50% of respondents have policies in place but not integrated and fully implemented. Despite these findings, 89.47% of respondents reported providing H&S training for employees, which is most often on-site safety training and education courses. When given a list of factors that have been verified to have a strong impact on H&S outcomes, the majority of respondents did not recognise these factors as essential or critical for implementation. The lack of consideration of H&S in planning and design stages was considered the item most responsible for H&S issues on construction sites, followed by lack of effective communications and lack of effective site planning. Moreover, findings reveal that KSA construction companies often lack full knowledge of the public construction sector landscape and that employees are often unaware of H&S policies and practices; therefore, these are not followed. This finding was further emphasised by their lack of consideration of H&S in planning and design stages, as well as their poor implementation of H&S procedures. However, respondents recognise the benefits of advancing H&S initiatives in terms of project schedule (91.67%), project budget (73.33%), company profitability (77.97%) and KPI (78.33%). Moreover, the majority of respondents (67.80%) agree that the use of mobile tools and technologies will positively impact the construction sector. Yet, none of the sample uses BIM for facility management purposes. The study found that most respondents that use BIM do so as a tool for project planning, while some use it for visualisation, design and for sustainability purposes. BIM is a multipurpose tool that can be used for all of the above-mentioned purposes, but most construction companies in KSA only use it for a single purpose, thereby limiting its ability to make a difference. This study also finds that most construction companies in KSA do not use BIM for all of their construction needs because they lack the technical know-how of its functionality.

Next, responses were compared by firm size to assess differences in micro-sized, small, medium and large firms. The larger the firm, the more likely it is that they make construction workers undertake induction training, with large firms most likely to carry these out. Small firms were most likely to report having good or advanced understanding of BIM (63%), but micro-sized firms have the lowest level of understanding. Large firms have the highest level of usage, but not the highest level of understanding. Thus, findings indicate that use is perhaps more of a factor of resources than of understanding. Despite these noted differences in firm size in the areas of training and BIM knowledge and usage, there did not appear to be large differences between respondents' attitudes towards factors considered responsible for H&S based on the size of the firm. However, medium and large firms were more likely to identify behavioural change as a mitigating factor.

Cross tabulations were also conducted based on the nature of the firm. The existence of H&S issues was fairly consistent across firm types, with consulting businesses having the highest rates of experiencing H&S issues on construction sites (100% reporting either "always" or "sometimes"). However, differences were observed in the use of BIM by firm type. Usage was highest for designing firms (85%), followed by other (75%) and consulting (63%), with general contracting businesses least likely to use BIM (57%). In so far as understanding of BIM is concerned, a difference by firm type in which designing firms exhibited the greatest understanding is also observed.

As regards statistical analysis, factor analysis, regression and ANOVA were conducted. Factor analysis was used to narrow the factor list from 18 to the eight most significant factors. These were then included in two regression models, one in which the dependent variable was use of construction safety policies and practices, and the second in which the dependent variable was frequency of H&S issues. Although these two models are not found to be statistically significant in explaining the dependent variable, one variable (firm size) was concluded to be statistically significant. Based on this finding, ANOVA was used to assess the difference in mean between the first size in relation to the factors. This study finds that there is a statistically significant difference in mean between micro-sized and large firms in two factors – 1) better communication devices for efficient information storage (*p*=.038) and 2) H&S incident reporting culture (*p*=.018).

6.4.2 Summary of Qualitative Findings

The interviews were analysed using thematic content analysis to ascertain the in-depth perceptions of H&S in the construction industry in KSA. The following seven themes were identified through analysis of the interview data: regulation; the migrant workforce – culture and communication; training; understanding of H&S matters; provision of safety equipment; environmental challenges; and BIM. Regarding regulation, there were many different beliefs and attitudes expressed by the interviewees, but many discussed the difficulties of trying to decide where to place the blame for the lack of regulation. Most indicated that it was the government that was at fault. Next, issues associated with the migrant workforce emerged as a major theme, with many respondents holding negative perceptions of the group and its associated challenges, such as problems of communication and cultural differences. Training issues also emerged as an important theme. While all interviewees recognise the importance of H&S training, there is an assumption that current training is adequate. This is also emphasised in the next theme—the lack of understanding of the real necessity of these matters. The next issue of consideration is inefficient safety equipment, signage and precautions. None of the interviewees have used BIM for modelling, but many acknowledge its potential value for the H&S of construction workers. Finally, a relationship map of the seven qualitative themes is presented in the next section to demonstrate the causal direction of the various factors. For instance, the lack of government regulation is considered to be cause of inefficiency in four of the other factors.

<u>Current H&S practices</u>

There is a slightly different emphasis given to the background question here and the reason for this may be that the questionnaire is very specific in asking about the ways in which H&S issues are seen in the practices of the relevant company. The reason for this could have been that the questionnaire specifically asks about the H&S issues at the outset, with a set of alternatives to choose from (fully integrated, present but not integrated, ad hoc and none), while in the interviews the question merely refers to challenges to H&S on construction sites: Therefore, the interview group tends to interpret the first question on challenges as broadly based and most answers highlight the lack of regulation in the industry. While this issue is widely discussed in many different forms by the interviewees, pointing the finger both at national guidance on H&S and site regulation, in the questionnaire regulation is placed very low on the list of priorities in H&S practices, ranking lowest, in fact. It might be said that the questionnaire asks about practice and the interview seeks an opinion. This is often the nature of quantitative/qualitative data and it is useful for balancing the findings of closed questions, which seek presumed facts, with attitude and beliefs and opinions. This is the strength of mixed methods.

An additional advantage of qualitative data collection is that it enables the interviewees to offer their own helpful suggestions, as it does in this case. This happens mostly in relation to regulation and how it could be enforced. Interviewee IA suggests encouragement bonuses for observance of H&S requirements. IB opines that owners be informed that any infringement of regulations and any accidents would result in a cancellation of insurance, while IC suggests the use of prevention by design and that there should be regular appraisals: "Construction workers tend to respect H&S precautions when they are convinced that this is associated with their appraisal by their supervisor". ID is interested in seeing observance of H&S to be included in the initial contract and in the "imposition of fines for every one including the contractors, because when, as the result of an accident, work stops, the budget of the project will rise". All these constructive suggestions as to how to change the current negligent practices are very useful in moving forward the proposed construction of a framework for H&S in the industry. In addition, several of the interviewees state a desire for the KSA construction industry to bring H&S up to international standards, which would seem to be a very sensible suggestion in the light of globalisation. In fact, one member of a management team, IH, works for such an organisation, a Chinese company operating in most countries in the world. His view about H&S and the sense of applying internal rather than externally imposed regulation is more practical but would only apply to private companies seeking reputation and profit:

> *'Indeed, our main motivation is to safeguard the health and safety of our workforce. They are the fundamental factor in completion of a project according to the timetable. This issue guarantees the continuation of our operation in the Saudi market and increases the trust of our clients in the competency of the company. The consequence would be our success in the region and increased value of our shares as an international company …. As you know, our company is pursuing profit, therefore finishing a project without any accidents results in the continuous flow of work without interruption. This in turn means completion of the project on time. Result: more profit and more trust building'.* IH

A strength of qualitative data is that there is little opportunity to invent or mislead, as it is difficult and unnecessary to do this in a face-to-face situation. Another of the emergent themes from the interviews is that of training and the belief that there is too little, generally, although no examples are given. However, in the questionnaire, there is a series of questions about training and some very useful and very specific answers. One that develops over several questions is that over 95% of respondents say that they know of their company's H&S practice and how it is operated, but the question of whether training should be held give rise to a number of contradictions. It is clear that training is restricted to induction training for new employees, which is used by 68% of companies. 60% state that all of the workforce should have dedicated H&S training. Yet, regular on-site meetings about H&S for all staff and safety audits are ranked very low as contributing to H&S welfare on construction sites and only 13% claim to have regular safety training for all staff. Fewer than one-quarter of participants think that these types of training are "very important". In contrast, the interviewees do not restrict the meaning of "training" to induction training but extend it to include education and qualifications, with one interviewee claiming that many of those seeking employment on his company's site had faked qualifications and training. The interviewees believe that training failures characterise the industry

Another issue that partially divides the interview group from the questionnaire group is that the former appears more ready to think of top-down organisation and practical interventions to improve current practices, while the latter, in reflecting that view to some degree and claiming that implementation of H&S practices is one of the main problems, tend to name personal qualities as a solution to any outstanding issues. Good communication is ranked as one of the most necessary practices, and leadership style and quality are also very important.

It could be said that those working on the sites tend to concentrate not only on this issue but others, too, such as personal qualities in ensuring that H&S measures are observed. There is an emphasis here on learning by experience from a supervisor that could be respected and would give time to ensure the workforce is safe. The role of the supervisor, not specifically the subject of a separate question but present in the responses given, is emphasised as being a helpful and perhaps mentoring and necessary part of current practices. This distinction between the rankings in importance of those (the interviewees) elements, who largely although separately decide on what is important, contrasts with the participants' experiential values and knowledge.

A kind of agreement between the two different types of collection and analysis exists in that while the questionnaire data point out that although H&S policies are known and 85% of respondents agree that they have experienced some site accidents and problems, the overriding view of that group is that being aware of H&S policies and implementing them are two completely different issues. This is the case even if, it could be added, participants and their construction sites are suffering problems that might have solutions. The interview group echoes that finding, with interviewees claiming that although H&S rules are known, the practical interventions to support these are absent. This accords with the view of a psychologist, who claims (Reason, 2000):

> "Deaths, injuries and environmental damage are conspicuous and readily quantifiable occurrences. Avoiding them as far as possible is the objective of the safety sciences. It is hardly surprising, therefore, that this darker face has occupied much of the attention and shaped so many of the beliefs about safety. The positive face, on the other hand, is far more secretive. It relates to a system's intrinsic resistance to its operational hazards. Just as medicine knows more about pathology than health, so also do the safety sciences understand far more about how bad events happen than about how human actions and organisational processes also lead to their avoidance, detection and containment" (p. 3).

This may be one of the challenges facing those who try to implement, through whatever means, a safety understanding and knowledge that creates a safety culture. The problems may lie in the application of any rules or regulation that might be understood. However, an acceptance seems to be present in those who answered the questionnaire that the very large number of accidents and threats to health that occur on construction sites are only to be expected – from falls and spills to machine handling and structural collapse and heatstroke. It is hoped that this study goes some way to contesting that belief.

Current H&S challenges

The interview group is also strongly aligned on the challenges facing work on construction sites. Overwhelmingly important to them, with references made to it in all interviews, is the challenge posed by the large migrant workforce. Although there is a specific question in the questionnaire about the role of various factors in the application of H&S practices in the workplace, multilingual, multicultural and low education were of low ranking proportionally. This appears to suggest that those working daily on construction sites or holding managerial positions cannot identify a causal chain leading from the employment of a workforce that is primarily from a different culture, through a language barrier and low education, to the incidence of accidents and the failure to establish a safety culture, generally. It is disappointing that the issue of the migrant workforce is so overlooked by this cohort.

The interviewees, on the other hand, do see the importance of this issue and the fact that it contributes considerably to the management of possible on-site hazards. IF notes: “Therefore, when you receive a worker, he lacks the culture to comply with health and safety regulations”. Interviewee B comments: “Workers come from different countries and their cultures differ greatly, as the result cooperation between them is very low”. Respondent II refers to the language barrier: “Some … don’t follow instruction in construction site because they misunderstand verbal and written site instructions”. Only one interviewee (IA) does not recognise and/or mention this important issue that is reflected so often in the literature (see Chapter 2). Salminen (2011), for example, concludes his meta-analysis of research on construction site accidents internationally with this statement:

> "This review showed that on average immigrants were involved in occupational injuries twice more often than native workers. This result is based on 31 studies from sixteen different countries. It shows that immigrant workers have a worse work life situation than the native population" (p. 127).

Another challenge to the weak safety culture is that KSA appears to have little technological development and workplace use. Online training, for instance, is limited to around 8%, while on-site training is claimed to stand at 80%. This could be said to show both a limitation of opportunities to allow internet reminders of H&S issues and further qualification that could be undertaken in the worker's own time and to the desired level. Workers showing this degree of interest and continuing development could contribute usefully to the development and promotion of a safety culture. In addition to that disappointing finding, another occurs in the context of how useful the employment of BIM would be, in terms of schedule, cost, on site safety and other issues: when asked whether hand-held technology would be a positive contribution to on-site safety, 68% agreed. This is the lowest approval rate of any of the items in that section of the questionnaire.

Generally speaking, therefore, it appears, as evidenced in the literature review, that technological advancement is not as pronounced in KSA as it might be in other countries in the developing world. Almost 20 years ago, O'Brien and Al-Biqami (1998) had argued that this was the case:

> "The construction industry in Saudi Arabia has been slow to employ IT. There appear to be no official statistics or comprehensive studies on IT use in the Saudi construction industry. To this point, there has only been a limited survey carried out by Shash and Al-Amir (1997). This survey focussed on the extent of computer use and their applications in construction contractor firms in Saudi Arabia. The findings indicate that computers are not widely used by construction contractors, especially in relation to those who are classified as small and medium-sized contractors. The use of computers is directly proportional to the size of the contractor firm. While, all large contractors use computers, only 41% and 62% of small and medium-sized contractors use them" (pp. 2327-2337).

Therefore, this evidence makes it clear why the indication in this study that BIM is relatively widely used is surprising, although it is seen in the questionnaire data only. The interview cohorts actually suggest otherwise and it is useful to examine the issue that produces the biggest discrepancy between the answers given in the questionnaire and the opinions offered in the interviews – namely, use of BIM. Therefore, the discussion moves to an examination of the third research question and possible reasons for the confusing and contradictory answers given to it.

BIM and its use for H&S

It is clear from the title of the thesis that the research study focuses on projected use of BIM to improve the current practices in H&S for construction sites, therefore this is the crucial matter in the investigations and explorations of this study. BIM is placed centre stage in this study and it builds from considering the current state of KSA construction industry, as far as H&S procedures, understanding and implementations are concerned, to examining the challenges that may cause shortcomings in H&S. A related area is whether BIM could facilitate enhancements to any of these issues and produce solutions to many of them. Another question is whether, given the responses of industry workers, managers and construction owners, a framework could be designed to enhance current H&S practices. Therefore, this final research question bears the weight of the entire thesis, given the evidence produced in questions 1 and 2 and the evidence that direct questioning on this issue might produce.

First, it is necessary to look at the results from the interviews. The finding is that this particular cohort has some knowledge but no experience of using BIM, even amongst those designers one might have thought would be using it habitually. Interviewee IA, while admitting that he has never used BIM, claims that while it may have an auxiliary effect on improving the level of H&S, it is not an "important factor". Interviewee IB, an architect, gives a very definite and definitive answer, already referenced, to the question about the use of BIM: "As far as I know, none of the construction companies in KSA have used it within the construction phase", although he does admit: "I think we could use augmented reality to present issues within H&S". Interviewee IC, another architect, says that he supports the concept of "prevention by design" and he heard of BIM, but that "we do not intend to utilise BIM for H&S". Interviewee ID has never used or come across it in his whole work experience but would like to. Interviewee IE, an engineer, has never used BIM but thinks it might be useful for site induction, Interviewee IF, a construction manager, states that he has heard about it but his company had never used it. Interviewee IG has not heard of BIM. Interviewee IH, a contractor, says that his company had never used it although he believes it would surely have a positive impact on H&S. Interviewee II, an architect with a PhD, has not heard of BIM and IJ, a contractor, could see that it might have some use but has never used it. In summary, none of the interviewees, many in powerful managerial and governmental roles, some academics, has ever used BIM and at least one has never heard of it. The most striking comment here, worth repetition, is that of IB, who claims that he has not heard of any construction company in KSA that has used it.

Attention then turns to the questionnaire responses, as this is where the discrepancy lies. In response to the question “Is your organisation using BIM?” 61% said yes. Therefore, of this questionnaire sample, taken from representatives in construction, design, site management, contractors and subcontractors, with large to micro-sized companies, claim use of something that the interviewees do not use. Furthermore, one interviewee states specifically that no construction site in Saudi Arabia uses BIM. Uses claimed of BIM are project planning and visualisation; yet, although one architect suggests that visualisation might be an excellent way to overcome the challenge of explaining building procedures in different languages to a migrant workforce, to his knowledge, it has not been used like this in KSA. Nor have any of the interviewees experienced its use in project planning, although IF claims that his company was about to introduce it. In the most bewildering of the questionnaire responses to the question seeking their knowledge of BIM, 11% claim “advanced knowledge” and 32% “good understanding”. With only 11% of participants saying that they had no understanding of it, this represents a serious contrast between the results from each different type of data collection method. In addition, although some participants skipped the questions on BIM, ranging from 12-30 missed responses, nevertheless over 150 of the cohort answered every one of these questions, so it is claimed that these are a representative sample. This group also appears to have a good understanding of the uses that BIM could be put to, most of them (80%) agreeing that it is useful for producing visualisation for the migrant workforce and possessing a clear perception that using BIM would save on costs, eliminate lost man-hours and accidents, and improve site safety and communication, as discussed in the literature:

> "The relative newness of BIM allows contractors the opportunity to increase profits by improving productivity while using pre-BIM productivity rates. This productivity is gained by clear visualisation of the component assembly and elimination of conflicts in the field. Labour does not stand idle waiting to determine how to install material because it was coordinated in the model. There is little rework done because of conflicts. Larger, prefabricated building components make it easier to perform more work in off site where working conditions are more amenable to higher production rates. These causes contribute to the reduction in the amount of time spent to erect the structure. Until more contractors are able to manage the coordination process and

> realise lower costs, there will continue to be an opportunity to gain BIM early adopters' profits" (Porwal & Hewage, 2013, p. 207).

Some of the participants had already identified the on-site challenges, so their responses were internally coherent. Also, education and training, and the time and cost they incur, are considered barriers to the initial implementation of BIM. This data from the questionnaire responses accords with evidence from the literature review and with the responses from interviewees. Interviewee IA, for example, claims: 'I don't think we can use it now because it needs educational provisions and facilities which might be costly', a point made by the majority of questionnaire participants.

6.5 Summary

This mixed methodology approach has produced what was not totally expected but partially accepted by those who commentate on research methods. It offers two different views and each of the methods could be regarded as more useful than the other in several of the research questions, bearing in mind that the object is to examine the issue of H&S on construction sites in KSA and whether the use of BIM could enhance current practice in that field. Therefore, the variation in response, which is due to a difference in methods and sample, has produced rich evidence to inform the possible construction of a framework for H&S in KSA. The materials for that framework and suggested use of BIM are explored in the next chapter.

Chapter 7. Enhancing the H&S Framework

7.1 Introduction

The main aim of this study is to develop a framework for enhancing H&S in the public construction sector in KSA. In this chapter, a rationale for framework development is presented, one that considers building a supplementary model to help managers in those Saudi construction companies implement the new technology to improve the H&S process. More specifically, this chapter reflects on the use of ISM as an effective method for developing such a model.

7.2 Existing H&S Frameworks

Ng, et al. (2005) framework of organisational H&S is presented as demonstration of best practice. This framework includes the need for administrative and management commitment to H&S (c.f. Baxendale & Jones, 2000; Abudayyeh et al., 2006; Anton, 1989; Ng et al., 2005; Choudhry et al., 2007), considerations of H&S in selection and control of subcontractors (c.f. Ng et al., 2005; Pink, 2008; Phau et al., 2010; Al-Khalil & Al-Ghafly, 1999), keeping a throughout record of all accidents (c.f. Ng et al., 2005; Lin et al., 2014; OSHA, 2002; Lawton & Parker, 2002), conducting regular and frequent safety reviews (c.f. Lin et al., 2014; Aksorn & Hadikusumo, 2008; Abudayyeh et al., 2006; Ng et al., 2005); conducting H&S training to communicate policies (c.f. Kartam et al., 1998; Hallowell, 2010; Sulankivi et al., 2010; Berger, 2008; Arastoo et al., 2013; Alasmari et al., 2012; Hassanein & Hanna, 2008; Awad, 2013; Abudayyeh et al., 2006; Ng et al., 2005) and, finally, governmental oversight through legislation, codes and standards (c.f. Ng et al., 2005; Cotton et al., 2005; OSHA, 2002; Anton, 1989). H&S best practices occur through a top-down approach in which action occurs at the administrative level. This chapter uses the data presented in Chapters 6, as well as expert review, to provide a H&S framework more specific to the KSA construction industry.

7.3 ISM

ISM is an effective and well-established means of identifying the different elements and relationships thereof that define a problem or similar issues. The essential idea is that with experience, expertise and skill, one can deconstruct a more intricate system into its fundamental building blocks and then rebuild the system to be a multilevel structured model.

ISM is basically utilised to show “shared mental models”. These shared models of subject matter experts surveyed and interviewed for the purpose of this study are used to compose a tentative theoretical framework because they encapsulate how these individuals understand and explain the particular phenomenon being studied (Warfield, 1974).

The first step of ISM is to identify the various elements underlying the problem, or any variables related to the issues, and then use a group solving technique to develop these elements. According to previous literature and evidence and data that have been collected, 18 fundamental challenges have already been determined. Therefore, to develop the basic understanding, we have use this existing structure and the data collected to be certain that the structure is in line with the specific difficulties of KSA’s public sector construction environment. The information was used to form a relationship matrix and the researcher proceeded to use this to develop an ISM model. The relevant subordinate relation is then determined. The outcome of this exercise is to be able to rank the challenges so that the interactions between them may be determined using ISM. It is also important to determine the various elements from the focus group and to build a structural self-interaction matrix (SSIM), in order to link the relationships between the components horizontally. This ensures that the ISM is more effective. A SSIM can be built by comparing the different pairs of elements once the element set and contextual relations have been decided upon. Following this, the SSIM can be converted to a reachability matrix (RM) and the transitiveness can be verified.

7.4 Characteristics of ISM

The procedures used in ISM are interpretive ones. This is due to the fact that the results of the groups determine whether the components are related or not and also the degree to which the components differ. It is important to highlight this factor, as it gives the framework in an interpretation of the awareness of the content and shows the special environment of the public construction sector in KSA. It is initially built on the foundation of a mutual relationship and then the structure as a whole is obtained from the complex set of components. This is an example of a modelling technique: the structure as a whole and the relationships that fall within it are depicted in a diagraph model. This ensures that the intricacies of the relationships between the components of the system are efficiently organised.

7.5 Steps in ISM Methodology

The entire ISM process consists of eight steps:

1. Identify the components related to the problem. This was carried out through a review of extant literature and data collection from subject matter experts.
2. Draw up the relationship between the components mentioned in the above step, in relation to which pairs of components will be analysed.
3. Build a SSIM of the various components that will show the pairings of the elements; verify transitiveness.
4. Create an RM from the SSIM.
5. Organise the RM into different levels.
6. Convert the RM into a conical form.
7. Draw up a digraph from the relationships in the RM and remove the transitive links.
8. Convert the digraph into an ISM model; this is done by replacing the component nodes with statements.

Following the above eight steps leads us to create and present the relationships that exist between the determined elements. With the contextual relationship between each of the determined elements and the presence of a relationship between any two elements (*i* and *j*), the correlative direction of the relationship is questioned. To continue, note the symbols used and their definitions to represent the direction of the relationship between two factors, *i* and *j*.

These symbols indicate the direction between two factors: from factor i to factor j; from factor j to factor I; bidirectional between the two factors; or that there is not a relationship between the two.

(a) V for the relation from factor i to factor j (i.e. factor i will influence factor j).

(b) A for the relation from factor j to factor i (i.e. factor i will be influenced by factor j).

(c) X for both direction relations (i.e. factors i and j will influence each other).

(d) O for no relation between the factors (i.e. barriers i and j are unrelated).

Based on the contextual relationships, the factor-to-factor level for each of the 18 factors was identified and the SSIM developed. To obtain consensus, the SSIM should be further discussed by a group of experts. On the basis of their responses, the SSIM is finalised.

RM: the next step in the ISM approach is to develop an initial RM from SSIM. For this, SSIM is converted into the initial RM by substituting the four symbols (i.e. V, A, X or O) of SSIM by 1s or 0s.

The rules for this substitution, which were used to prepare the initial RM, are as follows:

(a) If the (i, j) entry in the SSIM is V, then the (i, j) entry in the RM becomes 1 and the (j, i) entry becomes 0.

(b) If the (i, j) entry in the SSIM is A, then the (i, j) entry in the RM becomes 0 and the (j, i) entry becomes 1.

(c) If the (i, j) entry in the SSIM is X, then the (i, j) entry in the RM becomes 1 and the (j, i) entry also becomes 1.

(d) If the (i, j) entry in the SSIM is O, then the (i, j) entry in the RM becomes 0 and the (j, i) entry also becomes 0.

7.5.1 Level partitions

Antecedent sets and reachability sets are obtained for each factor from the final RM. The reachability set contains the factor and the other element that it may effect. The antecedent set contains the factor itself and the other factor, which may affect it. Thus, the intersection of these sets is obtained for all factors and varying levels of different factors are identified.

The union of the factors that are the same for the reachability and the intersection sets are contained in the top level of the ISM structure. These top-level factors are those that do not lead the other factors above their own level in the structure. When the top-level factor is determined, it is no longer contemplated. To find factors in the next levels of the structure, the process is repeated. This is performed until the level of every factor is determined.

7.5.2 Conical matrix

To create a conical matrix, one groups the factors of the same level across the rows and columns of the final RM. A factor's drive power is determined by adding the numbers of 1s in the rows. Adding up the numbers of 1s in the columns derives the dependence power. To determine the drive power and dependence power ranking, the highest ranks are given to those factors that have the most 1s in the rows and columns, respectively.

7.6 ISM Approach and H&S Measures in Construction Industry

The ISM procedure is most commonly used to determine shared mental models. These show how people generally grasp and explain an event being analysed. The information below shows the procedures used in this study, where ISM was applied to the measurement of H&S performance measures.

7.6.1 Model development

The primary goal of this study is to be able to determine and categorise a group of performance yardsticks using ISM as backing for the H&S measures in KSA's public sector construction industry. Having an expert opinion and practising specific management techniques (brainstorming, for example) are integrated into the ISM procedure for creating contextual relationships among variables.

The above suggestions that form part of the ISM methodology and add to this research were created with contributions from construction industry experts in KSA. This provides the research with the insights and experiences of those who face these challenges daily in that industry. Six experts were consulted, in order to assist in determining the contextual relationships and interactions between the measures. They were selected using a positional approach through which industry leaders were selected based on level of management role and invited to participate starting. This process started with those holding the highest position until the participation of six experts was secured.

An interview was conducted with each expert to gather information on the relationships among the performance measures. Firstly, the researcher identified the study's main goals and explained the meaning of each variable. This step was crucial to ensuring that the experts concentrated on the relationships between the components. Each expert's account was written individually to avoid any influences from between them. The answers were combined at a later stage to facilitate a more complete analysis of the types of relationships identified. The results were then presented to the experts to produce a final and complete matrix that showed their consensus.

Construct validity, internal validity, external validity and reliability are important issues in overall research design and, hence, in the overall effectiveness of a research study (Yin, 2009; Voss et al., 2002). Construct validity is the extent to which a test can measure what it is trying to measure; internal validity is the degree to which a study tries to eliminate any bias in the test; external validity is the degree to which the results of the test can apply to other situations; and reliability measures the consistency of a test.

Based on the results obtained from the various methods adopted (written reviews, questionnaires and interviews), the framework is comprised of the following 18 key components. However, the relationships between the components remain to be determined.

- Better enforcement of regulations and laws
- Cost of implementing H&S measures
- 3D/4D/5D visualisation/simulation
- Safety measures incorporated into design phase
- Proactive approaches, e.g. hazard assessments and safety planning
- Management of data from all processes, including H&S
- Better communication devices for efficient information sharing
- Strong and clear communication link between all stakeholders
- Safety training programme made available to all staff across the organisation
- Simpler modes of information exchange
- Good safety leadership abilities in site supervisors
- Regular site safety audits
- Regular on-site safety meetings
- Employee education and training (knowledge)
- Personnel's responsibility
- Safety equipment and gear in hazardous environments
- Changing behaviour of employees towards H&S measures
- H&S incident reporting culture

Step 1: SSIM

To analyse the relationships among the variables considered in the suggested set of performance measures, a contextual relationship of "A leads to B" was chosen as the focus. This means that experts were asked to identify the extent to which one variable leads to another. Keeping in mind the contextual relationship for each variable, the existence of a relationship between any two variables (*i* and *j*) and the associated direction of the relation was the basis of the questions asked of the expert panel. All possible pairs of performance measures were selected and the experts were requested to classify the relationship between two performance measures as (see Table 7-1):

A (measure *j* will be achieved by measure *i)*;

V (measure *i* will help achieve measure *j*);

X (measures *i* and *j* will help achieve each other);

O (measures *i* and *j* are unrelated).

Table 7-1: SSIM

No	List of factors for H&S measures	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	Regular on-site safety meetings	O	X	X	A	O	X	O	A	V	A	V	O	X	V	X	O	X	X
2	Regular site safety audits	O	V	X	A	O	A	O	O	V	A	V	X	A	X	X	O	X	X
3	Safety training programme available to all staff across organisation	O	V	X	O	X	O	A	O	V	X	V	O	V	O	X	X	O	O
4	Proactive approaches e.g. hazard assessments and safety planning	V	V	V	X	A	A	A	X	V	A	V	O	V	V	X	X	X	X
5	H&s incident reporting culture	A	O	A	A	O	X	A	A	X	A	A	X	A	X	A	O	X	A
6	Good safety leadership abilities in site supervisors	O	V	A	X	O	O	O	O	V	A	V	O	X	V	A	A	V	X
7	Personnel's responsibility	O	V	A	O	O	O	O	O	V	A	X	X	O	X	O	O	X	O
8	Employee education and training (knowledge)	X	V	A	O	A	O	A	O	V	X	X	X	A	V	A	A	A	A
9	Better enforcement of regulations and laws	O	V	V	X	O	V	V	V	V	X	X	V	V	V	V	X	V	V
10	Changing behaviour of employees towards H&S measures	O	X	O	A	O	O	X	O	X	A	A	A	A	X	A	A	A	A
11	Simpler modes of information exchange	X	O	X	X	A	X	A	X	O	A	O	O	O	V	X	O	O	V
12	Cost of implementing H&S measures	V	V	V	O	V	V	X	V	X	A	V	O	O	V	V	V	O	O
13	Safety measures incorporated into design phase	V	V	V	X	A	X	A	X	O	A	O	O	O	X	V	O	V	X
14	3D/4D/5D visualisation/simulation	O	O	X	X	X	V	A	V	O	O	V	O	O	O	V	X	O	O
15	Strong and clear communication link between all stakeholders	X	V	X	X	X	X	O	X	V	X	O	O	X	V	X	O	V	V
16	Management of data of all processes, including H&S	V	O	X	X	X	A	A	X	O	A	V	V	V	V	A	X	X	X
17	Safety equipment and gear in hazardous environments	O	X	O	A	O	A	A	O	X	A	A	A	A	O	A	A	A	X
18	Better communication devices for efficient information sharing	X	O	A	X	O	A	A	X	O	O	X	O	O	V	A	O	O	O

Step 2: RM

The SSIM is transformed into a binary matrix, called the initial RM, by substituting 1 or 0 for the original symbols, V, A, X and O. The rules for the substitution are the following:

(1) If the (*i, j*) entry in the SSIM is V, then the (*i, j*) entry in the RM becomes 1 and the (*j, i*) entry becomes 0;

(2) If the (*i, j*) entry in the SSIM is A, then the (*i, j*) entry in the RM becomes 0 and the (j*, i*) entry becomes 1;

(3) If the (*i, j*) entry in the SSIM is X, then the (i, j) entry in the RM becomes 1 and the (*j, i*) entry becomes 1;

(4) If the (i, j) entry in the SSIM is O, then the (i, j) entry in the RM becomes 0 and the (j, i) entry also becomes 0.

Following these rules, the initial RM for the variables is shown in Table 7.2. The final RM is obtained by incorporating the transitivity of the factors as enumerated in step 4 of the ISM approach. In this table, the driving power and dependence of each variable is also shown. The driving power of a particular variable is the total number of variables (including itself) it may help achieve (see final column of Table 7-2). The dependence power is the total number of variables that may help achieve the measure.

Step 3: Level partitions

The reachability and antecedent set for each variable is found from the final RM (Warfield, 1974). The "reachability set" for a particular variable consists of the variable itself and the other variables which it may help achieve (see Table 7-2). The "antecedent set" consists of the variable itself and the other variables which may help in achieving it.

Table 7-2: Initial RM

No	Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Driving Power
1	Regular on-site safety meetings	0	1	1	0	0	1	0	0	1	0	1	0	1	1	1	0	1	1	10
2	Regular site safety audits	0	1	1	0	0	0	0	0	1	0	1	1	0	1	1	0	1	1	9
3	Safety training programme available to all staff across organisation	0	1	1	0	1	0	0	0	1	1	1	0	1	0	1	1	0	0	9
4	Proactive approaches, e.g. hazard assessments and safety planning	1	1	1	1	0	0	0	1	1	0	1	0	1	1	1	1	1	1	13
5	Good communication	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	0	1	0	5
6	H&S incident reporting culture	0	1	0	1	0	0	0	0	1	0	1	0	1	1	0	0	1	1	8
7	Good safety leadership abilities in site supervisors	0	1	0	0	0	0	0	0	1	0	1	1	0	1	0	0	1	0	6
8	Personnel's responsibility	1	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	0	0	7
9	Employee education and training	0	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	15
10	Better enforcement of regulations and laws	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	4
11	Changing behaviour of employees towards H&S measures	1	0	1	1	0	1	0	1	0	0	0	0	0	1	1	0	0	1	8
12	Simpler modes of information exchange	1	1	1	0	1	1	1	1	1	1	1	0	0	1	1	1	0	0	13
13	Cost of implementing H&S measures	1	1	1	1	0	1	0	1	0	0	0	0	0	1	1	0	1	1	10
14	Safety measures incorporated into design phase	0	0	1	1	1	1	0	1	0	0	1	0	0	0	1	1	0	0	8
15	3D/4D/5D visualisation/simulation	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	0	1	1	14
16	Strong and clear communication link between all stakeholders	1	0	1	1	1	0	0	1	0	0	1	1	1	1	0	1	1	1	12
17	Management of data of all processes, including H&S	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	3
18	Safety equipment and gear in hazardous environments	1	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	5
	Dependence Power	8	13	11	9	5	8	2	9	13	5	12	6	7	15	10	6	10	10	

Subsequently, the intersection of these sets is derived for all variables. The variable for which the reachability and the intersection sets are the same is given the top-level position in the ISM hierarchy, as it will not help achieve any other variable above its own level. After the identification of the top-level element, it is discarded. Tables 7-3 to 7-13 reflect the 12 interactions conducted to develop the level partitions.

Table 7-3: Partition of RM: interaction 1

Measure	Reachability Set	Antecedent Set	Intersection	Level
1	1,2,4,5,6,8,10,13,16,17	1,2,4,6,9,11,13,15,16,17	1,2,4,6,13,16,17	
2	1,2,4,5,7,8,10,16,17	1,2,4,5,7,8,10,16,17	3,4,9,14,16	
3	3,4,6,8,9,10,14,16,17	3,4,9,12,14,16	3,4,9,12,15,	
4	1,2,3,4,5,6,8,10,11,15,16,17,18	1,2,3,4,9,11,12,13,14,15	1,2,3,4,11,15	
5	2,5,7,10,13	1,2,4,5,6,7,8,9,10,11,12,13,15,16,18	2,5,7,10,13	1
6	1,2,5,6,8,9,10,15,16,17	1,3,4,6,9,15,16	1,6,15	
7	2,5,7,8,10,17	2,5,7,8,9,16	2,5,7,8	
8	5,7,8,9,10,17,18	1,2,3,4,6,7,8,9,12,14,16,18	7,8,9,18	
9	1,2,3,4,5,6,8,9,10,11,12,13,15,16,17	3,7,8,9,15	3,8,9,15	
10	5,10,12,17	1,2,3,4,5,6,7,8,9,10,12,15,17	5,10,12,17	1
11	1,4,5,11,13,15,16,18	4,9,11,12,13,14,15,16,18	4,11,13,15,16,18	
12	3,4,5,8,10,11,12,13,14,16,17,18	9,10,12	10,12	
13	1,2,4,5,11,13,15,16,17,18	1,5,9,11,12,13,14,15	1,11,13,15	
14	3,4,8,11,13,14,15,16	3,12,14,15,16	3,14,15,16	
15	1,2,4,5,6,9,10,11,13,14,15,16,17,18	4,6,9,11,13,14,15,16,18	1,2,3,11,14,15,16	
16	1,2,3,5,6,7,8,11,14,15,16,18	1,2,3,4,9,11,12,13,14,15,16	1,2,3,11,14,15,16	
17	1,10,17	1,2,3,4,6,7,8,9,10,12,13,15,17	1,10,17	1
18	5,8,11,15,18	4,8,11,12,13,15,16,18	8,11,15,18	

Table 7-4: Partition of RM: interaction 2

Measure	Reachability Set	Antecedent Set	Intersection	Level
1	1,2,4,6,8,13,16	1,2,4,6,9,11,13,15,16	1,2,4,6,13,16	
2	1,2,4,7,8,16	1,2,4,6,7,9,13,15,16	1,2,4,7,16	
3	3,4,6,8,9,14,16	3,4,9,12,14,16	3,4,9,14,16	
4	1,2,3,4,6,8,11,15,16,18	1,2,3,4,9,11,12,13,14,15	1,2,3,4,11,15	
6	1,2,6,8,15	1,3,4,6,9,15,16	1,6,15	
7	2,7,8	2,7,8,9,16	2,7,8	2
8	7,8,9,18	1,2,3,4,6,7,8,9,12,14,16,18	7,8,9,18	2
9	1,2,3,4,6,8,9,11,12,13,15,16	3,7,8,9,15	3,8,9,15	
11	1,4,11,13,15,16,18	4,9,11,12,13,14,15,16,18	4,11,13,15,16,18	
12	3,4,8,11,12,13,14,16,18	9,12	12	
13	1,2,4,11,13,15,16,18	1,9,11,12,13,14,15	1,11,13,15	
14	3,4,8,11,13,14,15,16	3,12,14,15,16	3,14,15,16	
15	1,2,4,6,9,11,13,14,15,16, 18	4,6,9,11,13,14,15,16,18	4,6,9,11,13,14,15,16, 18	
16	1,2,3,6,7,8,11,14,15,16,18	1,2,3,4,9,11,12,13,14,15, 16	1,2,3,11,14,15,16	
18	8,11,15,18	4,8,11,12,13,15,16,18	8,11,15,18	

Table 7-5: Partition of RM: interaction 3

Measure	Reachability Set	Antecedent Set	Intersection	Level
1	1,2,4,6,13,16	1,2,4,6,9,11,13,15,16	1,2,4,6,13,16	3
2	1,2,4,16	1,2,4,6,9,13,15,16	1,2,4,16	3
3	3,4,6,9,14,16	3,4,9,12,14,16	3,4,9,14,16	
4	1,2,3,4,6,11,15,16,18	1,2,3,4,9,11,12,13,14,15	1,2,3,4,11,15	
6	1,2,6,15	1,3,4,6,9,15,16	1,6,15	
9	1,2,3,4,6,9,11,12,13,1 5,16	3,9,15	3,9,15	
11	1,4,11,13,15,16,18	4,9,11,12,13,14,15,16, 18	4,11,13,15,16,18	
12	3,4,11,12,13,14,16,18	9,12	12	
13	1,2,4,11,13,15,16,18	1,9,11,12,13,14,15	1,11,13,15	
14	3,4,11,13,14,15,16	3,12,14,15,16	3,14,15,16	
15	1,2,4,6,9,11,13,14,15, 16,18	1,3,5,10,12,13,15,16,17,1 9	1,3,12,13,15,16,17,	
16	1,2,3,6,11,14,15,16,18	1,2,3,4,9,11,12,13,14,15, 16	1,2,3,11,14,15,16	
18	11,15,18	4,11,12,13,15,16,18	11,15,18	

Table 7-6: Partition of RM: interaction 4

Measure	**Reachability Set**	**Antecedent Set**	**Intersection**	**Level**
3	3,4,6,9,14,16	3,4,9,12,14,16	3,4,9,14,16	
4	3,4,6,11,15,16,18	3,4,6,9,15,16	3,4,11,15	
6	6,15		6,15	4
9	3,4,6,9,11,12,13,15,16	3,9,15	3,9,15	
11	4,11,13,15,16,18	4,9,11,12,13,14,15,16, 18	4,11,13,15,16,18	
12	3,4,11,12,13,14,16,18	9,12	12	
13	4,11,13,15,16,18	9,11,12,14,13,15	11,13,15	
14	3,4,11,13,14,15,16	3,12,14,15,16	3,14,15,16	
15	4,6,9,11,13,14,15,16,18	4,6,9,11,13,14,15,16,18	4,6,9,11,13,14,15,16,18	
16	3,6,11,14,15,16,18	3,4,9,11,12,13,14,15,16	3,11,14,15,16	
18	11,15,18	4,11,12,13,15,16,18	11,15,18	

Table 7-7: Partition of RM: interaction 5

Measure	Reachability Set	Antecedent Set	Intersection	Level
3	3,4,9,14,16	3,4,9,12,14,16	3,4,9,14,16	5
4	3,4,11,15,16,18	3,4,9,11,12,13,14,15	3,4,11,15	
9	3,4,9,11,12,13,15,16	3,9,15	3,9,15	
11	3,4,5,94,11,13,15,16,18 10,14,16,17	4,9,11,12,13,14,15,16, 18	4,11,13,15,16,18	5
12	3,4,11,12,13,14,16,18	9,12	12	
13	4,11,13,15,16,18	9,11,12,13,14,15	11,13,15,	
14	3,4,11,13,14,15,16	3,12,14,15,16	3,14,15,16	
15	4,9,11,13,14,15,16,18	4,9,11,13,14,15,16,18	4,9,11,13,14,15,16,18	
16	3,11,14,15,16,18	3,4,9,11,12,13,14,15,16	3,11,14,15,16	
18	11,15,18	4,11,12,13,15,16,18	11,15,18	

Table 7-8: Partition of RM: interaction 6

Measure	Reachability Set	Antecedent Set	Intersection	Level
4	4,15,16,18	4,9,12,13,14,15	4,15	
9	4,9,12,13,15,16	9,15	9,15	
12	4,12,13,14,16,18	9,12	12	
13	4,13,15,16,18	9,12,13,14,15	13,15	
14	4,13,14,15,16	9,12,13,14,15	14,15,16	
15	4,9,13,14,15,16,18	4,9,13,14,15,16,18	4,9,13,14,15,16,18	6
16	14,15,16,18	4,9,12,14,13,15,16	14,15,16	
18	15,18	4,12,13,15,16,18	15,18	6

Table 7-9: Partition of RM: interaction 7

Measure	Reachability Set	Antecedent Set	Intersection	Level
4	4,16	4,9,12,13,14	4	
9	4,9,12,13,16	9	9	
12	4,12,13,14,16	9,12	12	
13	4,13,16	9,12,13,14,15	13,	
14	4,13,14,16	12,14,16	14,16	
16	14,16	4,9,12,13,14,16	14,16	7

Table 7-10: Partition of RM: interaction 8

Measure	Reachability Set	Antecedent Set	Intersection	Level
4	4	4,9,12,13,14	4	8
9	4,9,12,13	9	9	
12	4,12,13,14	9,12	12	
13	4,13	9,12,13,14,15	13,	
14	4,13,14	12,14	14	

Table 7-11: Partition of RM: interaction 9

Measure	Reachability Set	Antecedent Set	Intersection	Level
9	9,12,13	9	9	
12	12,13,14	9,12	12	
13	13	9,12,13,14,15	13,	9
14	13,14	12,14	14	

Table 7-12: Partition of RM: interaction 10

Measure	Reachability Set	Antecedent Set	Intersection	Level
9	9,12	9	9	
12	12,14	9,12	12	
14	14	12,14	14	10

Table 7-13: Partition of RM: interaction 11

Measure	Reachability Set	Antecedent Set	Intersection	Level
9	9,12	9	9	
12	12,	9,12	12,	11

Table 7-14: Partition of RM: interaction 12

Measure	Reachability Set	Antecedent Set	Intersection	Level
9	9	9	9	12

7.7 Interpretation of Framework

The main aim of this study was to develop a framework for enhancing H&S in the public construction sector in KSA (see Figure 7-1). In this section, the rationale of framework development is examined with reference to the literature review and to the results

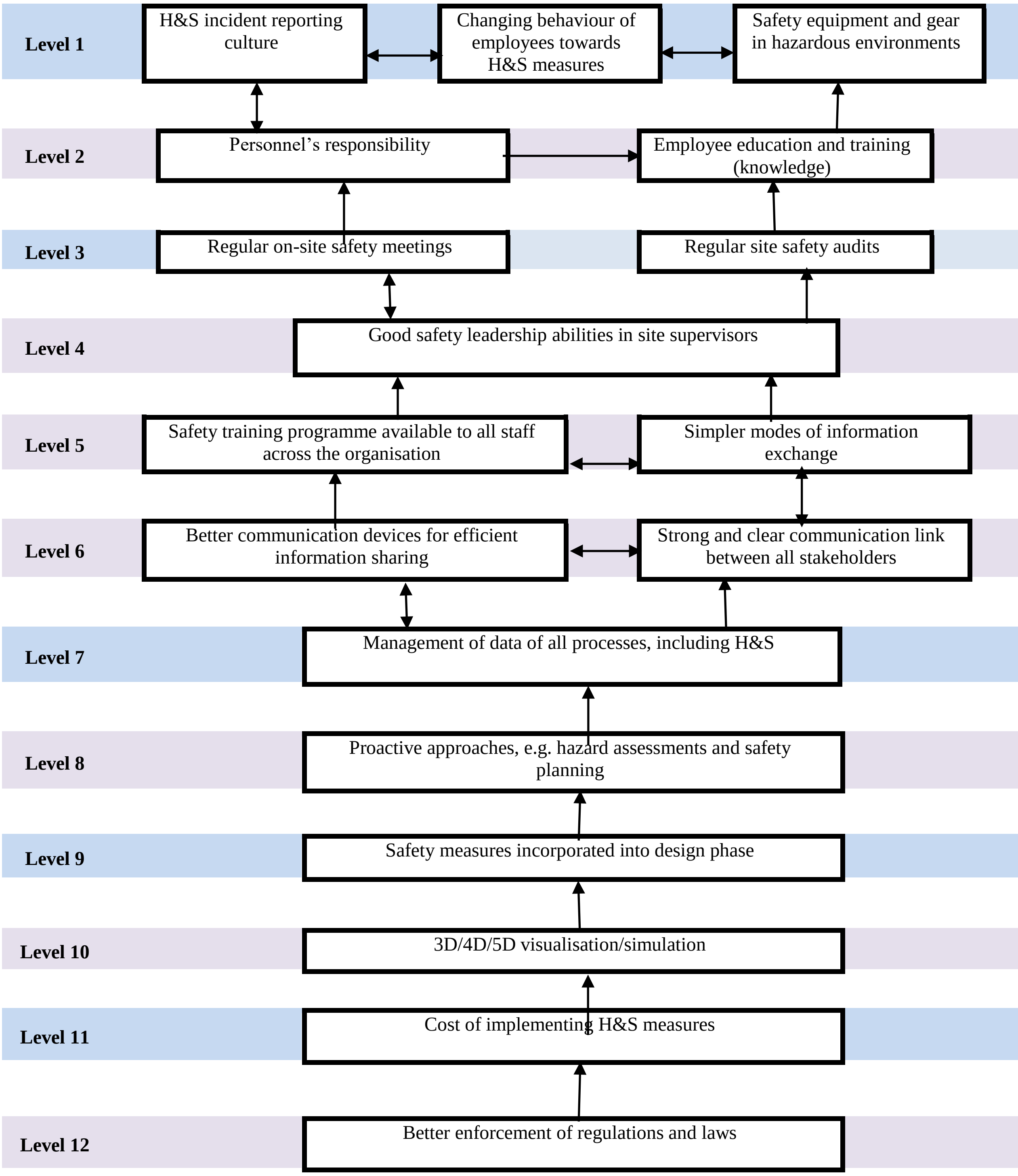

Figure 7-1:H&S framework

obtained from the questionnaire survey and interviews. Therefore, the details of the framework construction are provided, but it is important at this point to give meaning to ‘framework’. Determining the extent to which the identified factors contribute to effective H&S management is, as presented here, a complicated yet meaningful task. The framework, while specific to the environment of KSA, aligns with that indicated by Ng et al (2005). The reader’s attention is now directed to the model of risk management (Hinze & Russell, 1995) for considering factors for implementation:

- Knowing what the risks are and what in general should be done about them
- Planning, prioritising and implementing risk controls
- Ensuring that risk controls are effective and sustained
- Reviewing and learning

Therefore, a mixed method approach to identifying the risks and specific challenges of the KSA construction sector in terms of H&S has been taken. The proposed framework presents a hierarchical framework for planning, prioritising and implementing risk controls. The challenge now to practitioners and academics is to ensure that these tasks are implemented. Moreover, this study demonstrates that the tasks must be a priority for government regulation, as well as corporate administration. Thus, a top-down approach is emphasised for implementation of the framework.

The objective of this particular exercise was to collate opinions from a range of experts regarding the evidence supporting features associated with effective H&S management. Most of these key elements are very similar to those required for good quality, finance and general business management. The principles of good and effective management provide a sound basis for the improvement of H&S performance.

Following the interviews held individually with six construction experts, who were asked about the relation between 18 factors and which one has an impact upon which other one, the scope of the work was generated consisting of 12 different levels that all are related to each other (see Figure 7-1). Thus, some of the factors, when developed into a framework, were found to function at the same level. That was the result of the experts’ intervention, as all of them agreed on better enforcement of regulations and laws. Since this factor was the most important of all, it should have assured adherence to a decisive system of H&S within the any company and to the H&S regulations enacted by the government. It is important here to note that Ng et al. (2005) also identify this factor as the most important in the framework. Moreover, this assertion is supported by the extant literature (Baxendale & Jones, 2000; Toole, 2002; Abudayyeh et al., 2006; Anton, 1989; Ng et al., 2005; Choudhry et al., 2007).

The second most important factor is the cost of implementing H&S measures. There should be a sum assigned within the project budget for execution of all H&S measures.

What comes next is the 3D/4D/5D simulation/visualisation. At this stage, the 3D and 4D designs of the project are prepared to show every stage of construction with the scheduling. Next to that is design whereby dangerous locations in the project are located and eliminated. If any dangerous locations remain and cannot be eliminated, they should be avoided and evaluated in scheduling, so that, at every stage, an alert should be given. At the sixth stage, the S&H and method of its implementation will be designed; this will be a preventive stage for safety and protection of employees from accidents.

The next step is management of data of all processes, including H&S. The project intelligence and operating office that has safe implementation of BIM as part of its duty must ensure that all of previous stages have been executed properly. Recording and managing this information is an important issue. That is one of the advantages of BIM. In KSA, since projects are from different countries, communication between workers is a great challenge in the construction sector. Therefore, at level seven, it is assured that communication between all of the participants in the project, including management, employees and designers, is strong, that modern and fast communication devices are provided and that communication between participants is based on a joint relationship where each should have an impact on the other. Also, the connection between providing modern communication devices and management of information is a bilateral relationship.

There are two important factors at the eighth level – a safety training programme available to all staff across the organisation and simpler techniques of information exchange. The relation between them is bilateral, has an impact on each other, makes the transfer of information easy and provides courses for all personnel to understand signs and 3D plans. All of the experts agreed that conducting courses to elevate the knowledge of engineers and site personnel is an essential and basic issue. By doing so, their abilities and capability to understand instructions and information given by management is elevated.

At the tenth level, there are two important factors that depend on each other – regular site safety audits and regular on-site safety meetings. The first of these involves conducting meetings with employees, elaborating desired responsibilities and determining the duties of each one. Also, any dangerous locations should be introduced to employees and 3D images used to make understanding easy.

The other important factor at this level is monitoring activities through the daily watch and following up on all levels of project reporting, as well as reporting to management in case of encountering any hazardous item that was not predicted in the design but shows up during construction. In such a case, the designer will solve the problem and eliminate the hazard. This factor has an impact on the level of education and knowledge, since the level of education indicates the level of vigilance and follow-up. Therefore, if it is lacking in any way, it will be necessary to conduct courses to elevate the level of H&S. At this next level, personnel's responsibility preserves its effect and elevates its level. Periodic meetings will escalate knowledge and understanding of, and responsibility and obligation to the H&S rules and regulations.

In the final level consists of three factors:

1. Safety equipment and gear in hazardous environments.
2. Changing behaviour of employees towards H&S measures.
3. H&S incident reporting culture.

Knowledge and training are the most effective factors to keep up with the obligation to provide safety gear and protection, since they escalate the level of understanding of employees and management and ensure that H&S equipment is provided. These also changes the behaviour of employees, particularly those who have little experiences and are from those countries that do not pay much attention to H&S, who need to change their behaviour. This factor is related to reporting incidents in the context of the culture of employees and also individual responsibilities, since these have an impact on each other.

Step 5: MICMAC analysis – classification of performance measures

All performance measures have been classified into four categories, based on their driving power and dependence (Table 7-15). Figure 7-2 sums up the number of 1s in the rows and its dependence power by summing up the 1s in the columns (c.f. Raj, Attri, & Jain, 2012; Attri, Grover, Dev, & Kumar, 2012). Thus, the final row of the table

Table 7-15: Driving power and dependent power for elements

Factors		Driving Power	Dependent Power
RegSafMeet	1	10	10
RegSafAudit	2	9	10
SafTrainProg	3	9	6
Proactive	4	13	10
HSIncidRep	5	5	15
SafLead	6	8	7
PerResp	7	6	6
Knowledge	8	7	12
BetEnfor	9	15	5
ChangeBeh	10	4	13
InfoExch	11	8	9
Cost	12	13	2
SafMeas	13	10	8
DVis	14	8	5
StakeCom	15	14	9
DataMan	16	12	11
Equip	17	3	13
GoodCom	18	5	8

represents the dependence power and the final column of the table represents the summing power. The four categories are: (1) autonomous measures; (2) dependent measures; (3) linkage measures; and (4) independent measures. These categories are now determined by their position in the H&S framework.

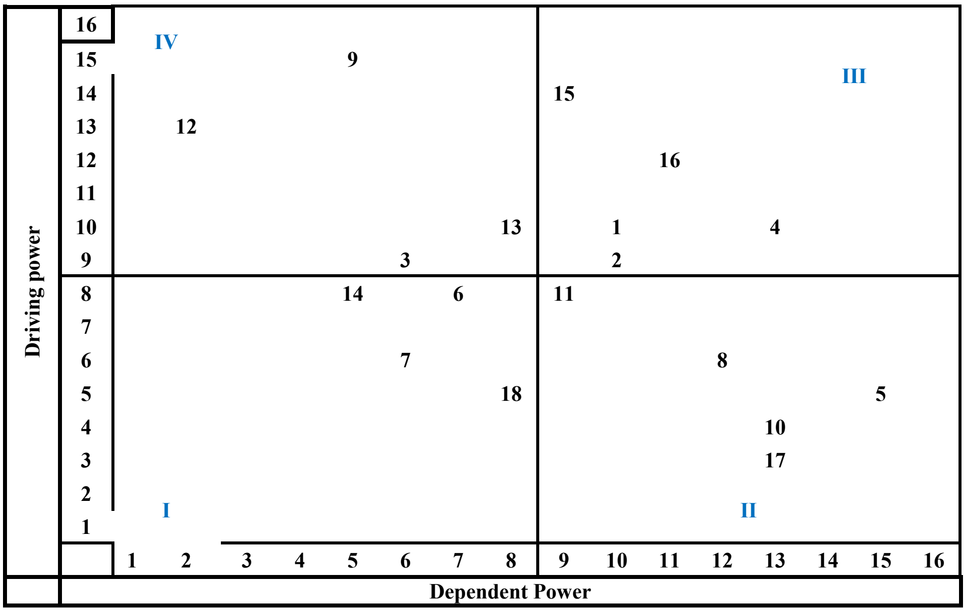

Figure 7-2: Classification factors

This classification of measures is similar to that used by Mandal and Deshmukh (1994). The driving power and dependence diagram for the suggested performance measures is shown in Figure 7-2.

Autonomous factors (weak driving power and weak dependence power) in the classification include: good safety leadership abilities in site supervisors (factor 6), personnel's responsibility (factor 7), better communication devices for efficient information sharing (factor 18) and 3D/4D/5D visualisation/simulation (factor 14). This means that they have little driving power and little dependence, and are relatively disconnected from the system. Dependent factors have weak driving power, but four factors indicate a strong dependence power: H&S incident reporting culture (factor 5), employee education and training (knowledge) (factor 8), changing behaviour of employees towards H&S measures (factor 10), simpler modes of information exchange (factor 11) and safety equipment and gear in hazardous environments (factor 17). The third cluster, consisting of independent factors (strong driving power but weak dependence power), has safety training programme made available to all staff across the organisation (factor 3), better enforcement of regulations and laws (factor 9), cost of implementing H&S measures (factor 12) and safety measures incorporated into design phase (factor 13). The fourth cluster consists of linkage measures that have strong driving power and high dependence linkage factors (those with strong driving power and strong dependence power), including regular on-site safety meetings (factor 1), regular site safety audits (factor 2), proactive approaches (e.g. hazards assessments and safety planning) (factor 4), strong and clear communication link between all stakeholders (factor 15) and management of data of all processes, including H&S (factor 16). Any action on these measures will have an effect on the other measures and also create a feedback effect on that measure itself.

7.8 Validation of Framework

The framework presented here has been validated in three ways. First, the methods used to obtain the framework are systematically outlined to allow for replication of the framework. In providing great detail on the research method and steps taken within it, the researcher provides transparency. Second, the framework is validated by its contextualisation into the existing discourse. As this based on the intersection of the literature provided in Chapters 2 and 3, the factors that were subjected to both qualitative and quantitative analysis are first identified through the research. Hence, the framework relates directly back to the research from which it was formulated. Furthermore, experts contributed to model development, providing it with face and content validity. Third, in using mixed methods and comparing the findings of the two approaches.

7.9 Summary

This chapter has presented the development of the framework to enhance H&S within BIM in KSA. This process began by highlighting some key findings of the literature review, followed by data collection to identify 18 factors. First, the ISM methodology was developed using the knowledge of experts in the construction industry to derive relationships among the suggested performance measures, which represents an element of bias. Also, as the research focuses on one specific industrial context, the findings are not universally applicable across different sectors or in different countries. There is also the possibility that different sectors might have different product and process characteristics, which could influence the type, ranking and relationships among the factors, leading to different results from using the ISM methodology.

Chapter 8. Discussion, Conclusion and Recommendation

8.1 Introduction

The previous chapters have introduced this study, provided an overview of the literature addressing the issue to be investigated, outlined the methodology employed to accomplish this, provided both quantitative and qualitative findings, and used these to develop a H&S framework that incorporates BIM. This dissertation brings the study full circle by relating these steps back to the five specific objectives listed in Chapter One.

The need to address these five aims has been demonstrated by the statistics surrounding the H&S of construction industry workers in KSA. To assess this issue and the potential of BIM for improving associated outcomes, this research began with an assessment of the extant literature addressing the KSA construction industry, including its organisation, challenges, H&S standards, regulations, safety culture and working practices. Next, the relevance of BIM for enhancing H&S outcomes was reviewed, focusing on communication and technology, BIM for safety, pre-construction considerations and the value of visualisation for a migrant workforce. Finally, an overview of the factors associated with existing H&S frameworks was provided. The overarching purpose of these five aims is to understand the applicability of existing H&S frameworks to the public sector construction industry in KSA.

8.2 Achievement of Research Aims and Objectives

To address the aims of this study, a mixed method approach utilising questionnaires (n=189) and interviews (n=10) has been employed. The survey data was analysed using descriptive statistics, cross-sectional statistics, factor analysis, OLS regression and ANOVA to develop a broad understanding of the conditions and perceptions in KSA public sector construction industry. Interview data were analysed using qualitative content analysis to develop a deep understanding of the relevant environment. The data from these two approaches was analysed to understand the existing H&S safety practices in the public construction sector in KSA, to investigate the relationship between BIM and H&S in construction, to develop an integrated framework for using BIM in construction to address H&S issues, to assess the framework developed through expert opinion and to provide concluding recommendations based on best practice, as well as provide direction for further research on this subject. The following sections note how these steps have met the first four aims of the study in turn. There follows a discussion of the contribution this research makes both theoretically and practically. Next, the limitations of the research and suggestions for future research are provided. Finally, to fulfil the fifth aim, the study concludes by making recommendations.

8.2.1 Objective 1: Explore existing practice of H&S

This research has assessed KSA construction sector H&S practices and how these compare to established best practice. The survey and interview data both indicate that the current practices in KSA are often haphazard and can be attributed to the high number of safety incidents in the country. The results reveal that 85% of survey respondents have experienced H&S issues in their construction projects. The literature suggests that high rates of occurrence are largely due to the lack of adherence to best practice by management (Arastoo et al., 2013; Alasmari et al., 2012; Hassanein and Hanna, 2008; Awad, 2013). Of the factors provided as best practice, respondents overwhelmingly do not recognise their value in improving H&S outcomes. Thus, if their value is not recognised, it is highly unlikely that they will be rigorously implemented to improve outcomes.

Interviewees indicate that working with a largely migrant workforce is one of the greatest challenges associated with H&S performance management in KSA. This finding aligns with that of Alsehaimi (2011), who identifies KSA construction sector's heavy dependence on multicultural, multilingual, low and semi-skilled labour as one of the main factors impacting its H&S performance. De Bel-Air (2013) confirms that the construction industry in KSA is heavily reliant on migrants from South Asia and that these workers often only have basic education, many barely literate.

8.2.2 Objective 2: Identify relationship between BIM and H&S

BIM, it is found, stands to improve H&S outcomes uniquely through addressing the challenges expressed by the study respondents. As it is clear that communication is an issue, visualisation through BIM cuts across barriers of language. Not only does BIM allow for visualisation and translation in H&S training materials, but also for safety measures to be incorporated in the design phase of a construction project and opportunities for 3D/4D/5D visualisation and simulation. Therefore, the findings reveal that BIM improves opportunities for strong and clear communication links between all stakeholders.

Currently, one-third of KSA construction companies are taking advantage of BIM and related technologies. However, it is important to note that the current use and implementation of BIM is sporadic and far from meeting its potential. Khosravi et al. (2014) note that it is an approach, not just a software tool. Over three-quarters of the study sample agree that BIM will positively impact on-site construction safety. This study finds that there is a significant and direct positive impact of investment on H&S on construction projects in KSA construction sector. This has been established by the responses received and studies have shown that investment in H&S can impact construction projects greatly.

The study also finds that most construction companies in KSA do not use the BIM tool for all of their construction needs because they lack the technical know-how. Despite lack of widespread usage, most construction companies note a desire to increase usage, yet are stifled by this ignorance of the functionality of the tool. Thus, the findings reveal that the greatest challenge and obstacle to the successful and effective implementation of BIM as a tool for the management of H&S in firms is education and training, followed by behavioural change and improving communication.

8.2.3 Objective 3: Develop integrated framework

This study is motivated by the empirical need to develop a framework for enhancing H&S outcomes in KSA public sector construction industry. Two factors have been identified and used in an existing framework (Ng et al., 2005) and risk management model (Hinze & Russell, 1995). Subject experts were surveyed and interviewed, and the potential to improve these outcomes using BIM was assessed. Overall, the findings reveal that in consideration of the 1) dramatic gap between H&S best practice and current KSA practices, 2) the identification of the migrant workforce as a key challenge in improving H&S outcomes and 3) the current lack of usage of BIM, implementation of BIM approaches is an appropriate response for improving H&S outcomes in KSA public sector construction industry. Thus, the framework developed in this study was built using ISM to support the evaluation of H&S measures and the relationships they share. Eighteen key elements of H&S were identified:

1. Better enforcement of regulations and laws.
2. Cost of implementing H&S measures.
3. 3D/4D/5D visualisation/simulation.
4. Safety measures incorporated into design phase.
5. Proactive approaches e.g. hazard assessments and safety planning.
6. Management of data of all processes, including H&S.
7. Better communication devices for efficient information sharing.
8. Strong and clear communication link between all stakeholders.
9. Safety training programme me made available to all staff across the organisation.
10. Simpler modes of information exchange.
11. Good safety leadership abilities in site supervisors.
12. Regular site safety audits.
13. Regular on-site safety meetings.
14. Employee education and training (knowledge).
15. Personnel's responsibility.
16. Safety equipment and gear in hazardous environments.
17. Changing behaviour of employees towards H&S measures.
18. H&S incident reporting culture.

8.2.4 Objective 4: Test, evaluate and validate framework

This study draws synthesis between the qualitative and quantitative findings through ISM, which it uses to identify and rank a set of performance measures to support the evaluation of H&S factors in the construction industry. Relying on experts from the H&S construction industry, ISM and associated H&S framework was developed. The interview and survey data were used to assess the relationship between these 18 factors and differentiate them at 12 different levels, as well as determine the relationship between them. Moreover, expert review by industry leaders was used to provide face and content validity for the proposed framework. The framework was also deriver, in part, from the established literature, as presented in Chapters 3 and 4. In classifying these outcomes using the methods of Mandal and Deshmukh (1994), the factors were determined as driving measures, linking measures, autonomous measures or dependent measures. Although the following framework and suggested cluster of performance measures were provided in Chapter 7.

The framework indicates that, like in the qualitative analysis causal framework, a key concern is the lack of enforcement of laws and regulations. This also aligns with the framework presented by Ng et al. (2005). It takes into consideration established best practice, the challenges identified by respondents in this research and the application of BIM for improving H&S outcomes. As technological advances, most notably the use of BIM, stand to address the primary challenge indicated in this research—communication with the migrant workforce—the addition of 3D/4D/5D visualisation is the major deviation from previous models of H&S.

8.3 Contribution to Knowledge

This research has made a contribution in three areas. First, factors that affect H&S performance in KSA public sector construction industry are identified. Second, a deeper understanding of utilising BIM to support the H&S outcomes of this sector is developed. Third, contributions are made to a framework for enhancing H&S practice through new and available ICT technologies. In its efforts to mitigate future H&S incidents, this study can improve the conditions for a number of people. To this effect, the researcher has proposed and assessed the use of new technologies and best practices to address the problems identified. As these areas have not been studied in the Saudi context, these contributions have both academic and practical applications. Academically, the findings of this study provide a baseline for knowledge of H&S in the Saudi construction industry, an area in which gaps have previously been identified in the literature. Practically, the findings of this study can be used to identify areas of improvement with actionable outcomes. For instance, the findings reveal that lack of government regulation is a contributory factor to the high rate of H&S incidents and that BIM is a potential tool for addressing these issues. Thus, the final recommendation of this study is for both government and firms to consider the findings of this study when developing policies to implement change and improve outcomes.

Although this study has identified the challenges faced and reconceptualised the H&S model for the environment assessed, the task of making substantive changes remains.

The old adage "you can lead a horse to water, but you can't make it drink" is fitting from a practical application standpoint, as this knowledge is only useful insofar as it has the capability to result in change. Just as there are many noted benefits for the use of BIM, as has been highlighted through this study, there are notable challenges (Kiviniemi et al., 2011; Hartmann & Fischer, 2007). Two scenarios are seen that would act as catalysts for change to improve the likelihood of measures for better H&S outcomes in the KSA public sector construction industry. First, it is noted that until there is widespread education relating to how BIM works, how it can provide a visual, immediate and sequenced insight into how a building can be perceived and projected, and how those who work in it can be protected, the unique safety features availability through BIM may not be recognised and implemented. Second, through a literature review and analysis of the perceptions of subject experts, this research acknowledges the lack of government oversight in the form of regulations, codes and policies. This is a factor that is consistently emphasised across H&S frameworks, yet has not been realised in this context. Greater government action is needed, such as that demonstrated by OSHA in the USA or the Health and Safety at Work Act in the UK. This would force the hand of construction firms and make them pay greater attention to factors and practices, including BIM, that would likely improve H&S outcomes.

Although this research has studied the case of the construction industry in KSA, many of the challenges that were revealed align with the literature and are likely present across other industries and countries. This research has been conducted to improve the human condition through identifying systematic, independent factors impacting H&S outcomes so that this knowledge can be used to improve conditions. Currently, more than half of all workplace injuries in KSA occur within the construction industry (Hamalainen, Takala, & Saarela, 2006), yet little has been done to improve these outcomes.

8.4 Limitations

As no study is without limitations, it is important to acknowledge these here. Three limitations are identified, all of which are used to develop and present suggestions for future research. The first limitation is the generalisability of the proposed framework. Although rigorous scientific methods have been adhered to in developing the proposed framework, it is based on data collected for a single case—the KSA public sector construction industry. Thus, the researcher recommends future research on the applicability of this model to: 1) the construction industry in similar countries; and 2) similar industries in KSA. Next, while the proposed framework has presented the relationship between performance measures and the classification of each through the proposed framework, it is not within the scope of this study to provide an in-depth explanation of the manner in which each of these 18 factors can be implemented to improve outcomes. Therefore, further research is needed to provide a deeper understanding of how these findings can be implemented and their practical applications. Finally, this study has assessed the use of BIM at one period in time and compared it to measures of H&S. A limitation of this approach is that it is not able to assess the impact that the implementation of BIM has had on firm H&S outcomes. This limitation provides the final recommendation for future research: a longitudinal study of the adoption of H&S measures is recommended, including BIM approaches, to assess the impact on outcomes through a comparison of H&S rates before and after adoption and/or policy changes.

8.5 Recommendations for KSA Construction Industry

Although this research has studied the case of the construction industry in KSA, many of the challenges that were revealed align with the literature and are likely present across other industries and countries. This study has been conducted to improve the human condition through systematic, independent factors impacting H&S outcomes, so that this knowledge can be used to improve conditions. Currently, more than half of all workplace injuries in KSA occur within the construction industry (Hamalainen et al., 2006), yet little has been done to improve these outcomes. Based on the findings presented throughout this study, recommendations for KSA construction Industry can be drawn from the framework and addressed by implementing the framework into policy. As a key H&S concern, as demonstrated in the framework presented here and in that of Ng et al. (2005), is the lack of enforcement of laws and regulations, the first recommendation is to implement and enforce policies that ensure that best practices are adopted in the KSA construction industry. The second overarching recommendation is to incorporate the use of BIM into H&S policies, as this is essential for addressing one of the key challenges expressed by respondents in this study—language and communication barriers. This recommendation hinges on the addition of 3D/4D/5D visualisation, which is the main deviation in this framework when it is compared to previous H&S models.

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Appendices

Appendix 1: Ethical Approval

Academic Audit and Governance Committee

College of Science and Technology Research Ethics Panel (CST)

University of Salford MANCHESTER

To	**Yahya Ali Balgheeth (and Zeeshan Aziz)**
cc:	**Professor Hisham Elkadi, Head of School of SOBE**
From	**Nathalie Audren Howarth, College Research Support Officer**
Date	**22/01/2015**

MEMORANDUM

Subject:	**Approval of your Project by CST**
Project Title:	**Critical Success Factors for Enhancing Health and Safety Performance in Saudi Construction industry**
REP Reference:	**CST 14/30**

Following your responses to the Panel's queries, based on the information you provided, I can confirm that they have no objections on ethical grounds to your project.

If there are any changes to the project and/or its methodology, please inform the Panel as soon as possible.

Regards,

Nathalie Audren Howarth
College Research Support Officer

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Appendix 2: Preliminary Survey – Online Questionnaire 2015

Enhancing Existing Health and Safety Processes in Public Sector Construction Projects within Saudi Arabia using Virtual Design and Construction Approaches

Top of Form

Respondent Demographics

What is the size of your construction company?

- ○ Micro Sized (1 to 9 Employees)
- ○ Small Sized (10 to 50 Employees)
- ○ Medium Sized Firm (51 - 250 Employees)
- ○ Large Firm (250 or more employees)

What is the nature of your business??

- ○ General contracting
- ○ Designing
- ○ Consulting
- ○ Specialist sub-contracting
- ○ Other: ☐

What sort of projects you are involved in ?

Specify % of type of projects you have been involved in.

- ○ Public Sector Projects 100%
- ○ Private Sector Projects 100%
- ○ Combination of Public and Private Sector Projects

How many years of experience have you had in construction?

- ○ 0-5 years
- ○ 5-10 years

- 10 - 15 years
- 15 years +

Have you experienced health and safety issue in construction projects you have been part of?

- Yes
- No

If you have experienced H&S issues on your projects, how often does it occur?

- Always
- Sometimes
- Rarely
- Frequently
- Never

What are the common health and safety hazards to workers on your projects?

Please tick all those that apply

- Hazardous substance
- Heat Exhaustion
- Plants and Equipment
- Slips, trips and falls
- Structural collapse and accident in excavation
- Fire outbreak
- Fall from height
- Crane collapse and falling off load
- Electrical hazard
- Noise and vibration
- Asbestos and chemicals exposur

- [ ] Manual handling
- [ ] Other: ☐

Is your orgainsations using Building Information Modelling?

○ Yes

○ No

If BIM is used within your organisation, what purposes it is being used for?

- [ ] Project planning
- [ ] Visualisation
- [ ] Design
- [ ] Site Planning
- [ ] Clash detection
- [ ] Estimating
- [ ] Sustainability
- [ ] Facility management
- [ ] Pre Fabrication or Off-site manufacture
- [ ] Other: ☐

How will you describe your current understanding of BIM?

○ Advanced understanding

○ Good understanding

○ Basic understanding

○ No understanding

Which of these BIM software packages are you familiar with?

- [ ] Revit
- [ ] Tekla
- [ ] ArchiCAD

- VectorWorks
- Microstation
- Other:

Is your orgainsations involved in projects regularly involving prefabrication/modularisation?

- Yes
- No
- Other:

Understanding of Existing Practices

This Section asks questions related to prevailing Health and Safety Management Practices

Use of Construction Safety Policies and Practices within your firm?

- Fully integrated and widely observed construction safety programme
- Construction safety programme exists but is not fully integrated
- Adhoc approaches to construction safety - no formal policy however, occasional conduct of construction safety review
- No construction safety programme

Please check Health and Safety Practices currently used by your firm?

- Construction site workers undertake induction training
- There is a due process in place to investigate all reported Health and Safety incidents are investigated
- We maintain an on-site register to record any hazards reported by workers
- We analyse site safety hazards in pre-construction stage
- We have a designated project safety personnel to manage on-site safety
- We have regular training programme for our site staff and sub-contractors

☐ We have clearly defined Safety Key Performance Indicators

☐ We follow "safety by design" process by analysing safety hazards in pre construction stage

Please rate importance of the following factors for the safety programme?

	1. Extremely Low	2.	3.	4.	5. Extremely High
Regular On-Site Safety Meetings	○	○	○	○	○
Regular Site Safety Audits	○	○	○	○	○
Safety Training Programme available to all staff across organisation	○	○	○	○	○
Proactive approaches e.g. Hazards assessments and safety planning	○	○	○	○	○
Good Communication	○	○	○	○	○

	1. Extremely Low	2.	3.	4.	5. Extremely High
H&S Incident Reporting Culture	○	○	○	○	○
Good Safety leadership abilities in Site Supervisors	○	○	○	○	○
Personnel's Responsibility	○	○	○	○	○
Better enforcement of regulations and laws	○	○	○	○	○
Changing behaviour of employees towards H&S measures	○	○	○	○	○

Simpler modes of information exchange	○	○	○	○	○
Cost of implementing H&S measures	○	○	○	○	○
Safety measures incorporated in designing phase	○	○	○	○	○
3D/4D/5D visualization/simulation	○	○	○	○	○
Strong and clear communication link between all stakeholders	○	○	○	○	○
Management of data of all processes including H&S	○	○	○	○	○
Safety equipment and gear in	○	○	○	○	○

hazardous environments					
Better communication devices for efficient information sharing	○	○	○	○	○

Which of these do you consider responsible for health and safety issues on construction site? (Please rank them 5= most and 1 = least)

	1. Least	2.	3.	4.	5. Most
Lack of effective communications	○	○	○	○	○
Lack of effective site planning	○	○	○	○	○
Poor implementation of H&S implementation procedures	○	○	○	○	○
Lack of Regulations	○	○	○	○	○

	1. Least	2.	3.	4.	5. Most
Human Errors	○	○	○	○	○
Lack of H&S reporting culture	○	○	○	○	○
Lack of consideration of H&S in planning and design stages	○	○	○	○	○
Multi culture	○	○	○	○	○
Low Education	○	○	○	○	○
Multilingual	○	○	○	○	○

Understanding Construction Health and Safety Attitudes and Perceptions

This Section focuses on set of questions to better understand construction Health and Safety attitudes.

Do you prepare formal risk assessment and method statement for any of your projects?

○ Yes

○ No

For safety training, what is the most effective method?

○ Onsite Safety Training and Education

○ Online training

○ Certification Programme for site safety

How will investment in safety programme impact project schedule?

○ Positive Impact

○ Negative Impact

How will investment in safety programme impact project budget?

○ Positive Impact

○ Negative Impact

How will investment in safety programme impact company‘s profitability?

○ Positive Impact

○ Negative Impact

How will investment in safety programme impact project quality?

○ Positive Impact

○ Negative Impact

How will investment in safety programme impact safety KPIs (e.g. injuries)?

○ Positive Impact

○ Negative Impact

What impact earlier involvement of contractors in design and construction stage can make on construction projects?

○ Positive Impact

○ Negative Impact

How can BIM Impact on-site construction safety?

○ Positive Impact

○ Negative Impact

○ No impact

How does use of off-site construction techniques and processes impact construction safety?

- Positive Impact
- Negative Impact
- No impact

How does use of mobile tools (e.g. phones, tablets) could impact construction safety?

Please specify type of mobile device (e.g. Smart Phone, iPAD, iphone, other) that could have a greatest impact on improving site safety

- Positive Impact
- Negative Impact
- No impact
- Other:

Understanding of Potential of BIM applications for Enhancing Construction Health and Safety

According to statistics, UK construction industry consist of workers of different nationalities with different languages. Do you consider BIM an important tool for site induction? (Please tick one) *

- Strongly agree
- Agree
- Neither agree not disagree
- Disagree
- Strongly Disagree
- Other:

BIM has the potential to check for compliance to regulation on health and safety risk. Do you consider the integration of BIM into building regulation (BIM4regs) a positive development to the management of health and safety?

- Strongly agree
- Agree
- Neither agree not disagree
- Disagree
- Strongly Disagree
- Other:

How would you describe the benefits derive from the implementation of BIM in the management of health and safety within your organisation? (Please tick as many as applicable to your organisation)

- Eliminates lost MANHOURS
- Eliminates accidents
- Improves communication
- Improves construction safety
- Reduce Cost
- Other:

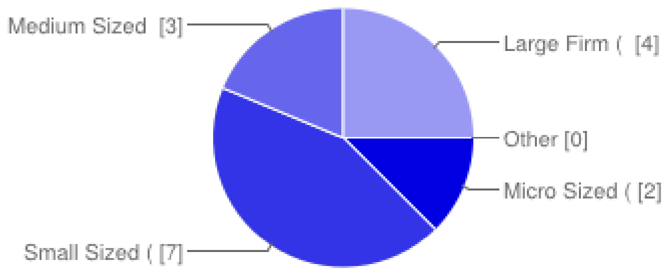
Which of these do you consider as barriers to the full implementation of BIM in the management of health and safety within your organisation? (Please tick as many as applicable to your organisation)

- Behavioural change
- Education and training
- Information Exchange
- Cost of Implementation
- Time required to train staff
- Other:

Appendix 3: Pilot Study

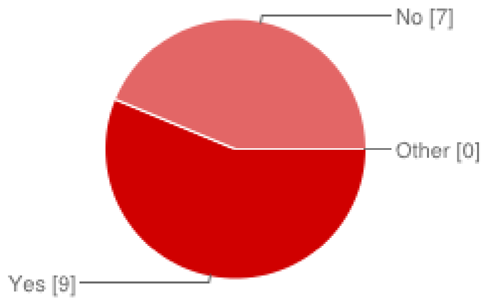
Section 1: The Organisation.

What is the size of your construction company?

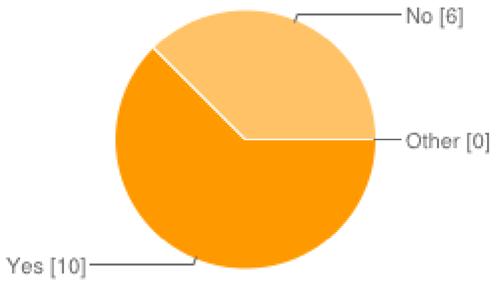


Micro Sized (1 to 9 Employees)	2	13%
Small Sized (10 to 50 Employees)	7	44%
Medium Sized Firm (51 - 250 Employees)	3	19%
Large Firm (250 or more employees)	4	25%
Other	0	0%

Is your orgainsations using Building Information Modelling?

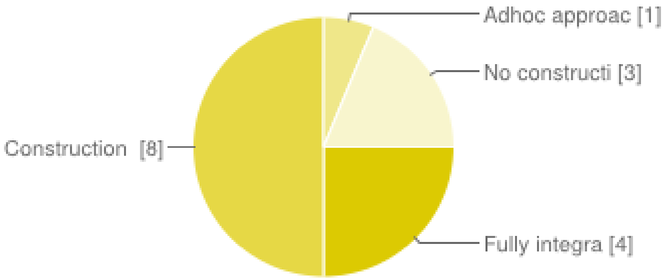


Is your orgainsations involved in projects regularly involving prefabrication/modularisation?



Section 3: The current Health and Safety practices.

Use of Construction Safety Policies and Practices within your firm?



Fully integrated and widely observed construction safety programme	4
Construction safety programme exists but is not fully integrated	8
Adhoc approaches to construction safety - no formal policy however, occasional conduct of construction safety	1
No construction safety programme	3

Please check the Health and Safety Practices currently used by your firm?

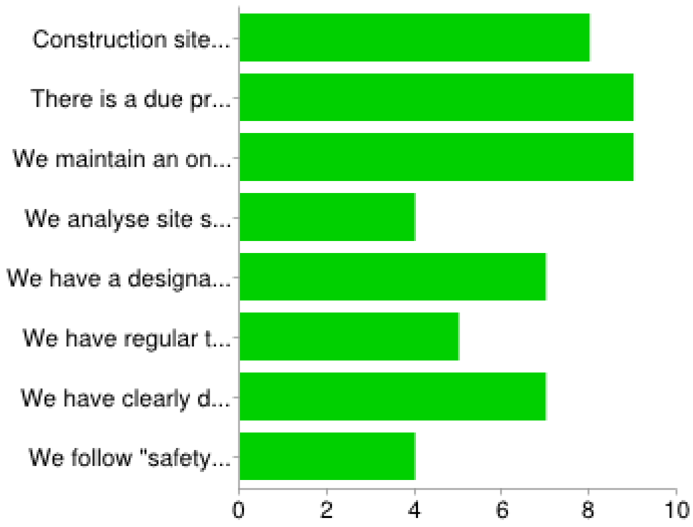
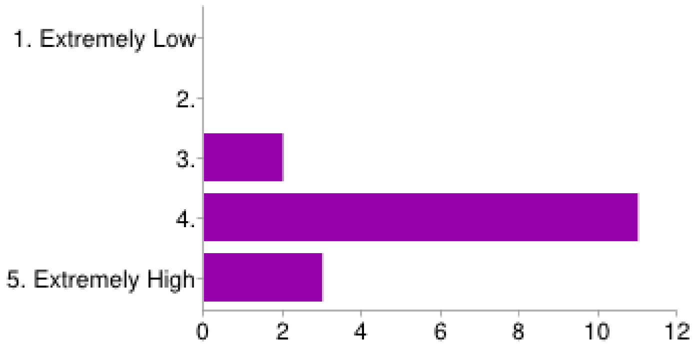


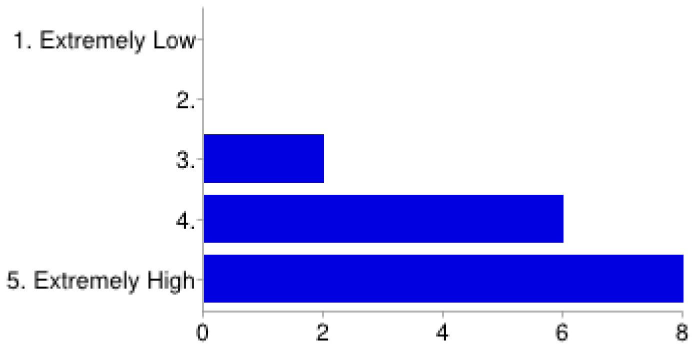
Table1; The Health and Safety Practices currently used

Construction site workers undertake induction training 8	There is a due process in place to investigate all reported Health and Safety incidents are investigated 9
We maintain an on-site register to record any hazards reported by workers 9	We analyse site safety hazards in pre-construction stage 4
We have a designated project safety personnel to manage on-site safety 7	We have regular training programme for our site staff and sub-contractors 5
We have clearly defined Safety Key Performance Indicators 7	We follow "safety by design" process by analysing safety hazards in pre-construction Stage 4.

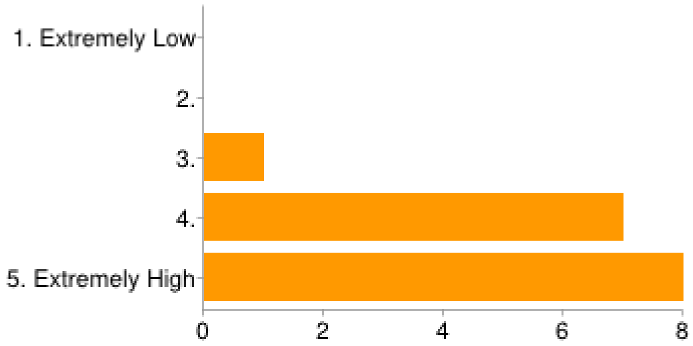
Regular On-Site Safety Meetings [Please rate importance of the following factors for the safety programme?



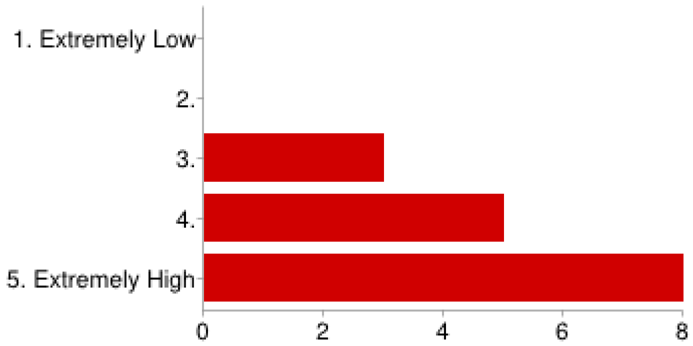
Regular Site Safety Audits [Please rate importance of the following factors for the safety programme?



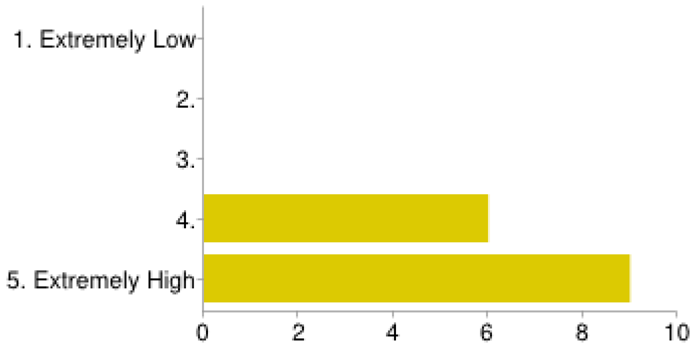
Safety Training Programme available to all staff across organisation [Please rate importance of the following factors for the safety programme?



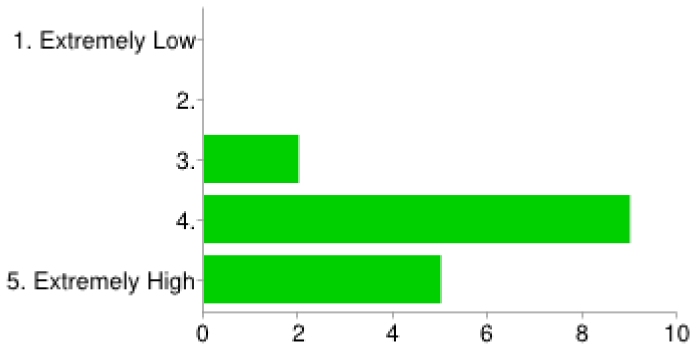
Proactive approaches e.g. Hazards assessments and safety planning [Please rate importance of the following factors for the safety programme?



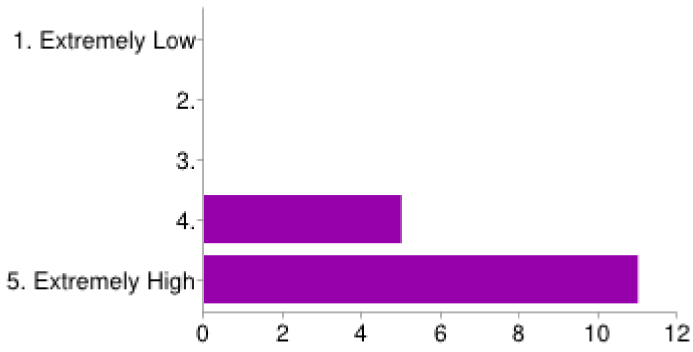
Good Communication [Please rate importance of the following factors for the safety programme?



H&S Incident Reporting Culture [Please rate importance of the following factors for the safety programme?

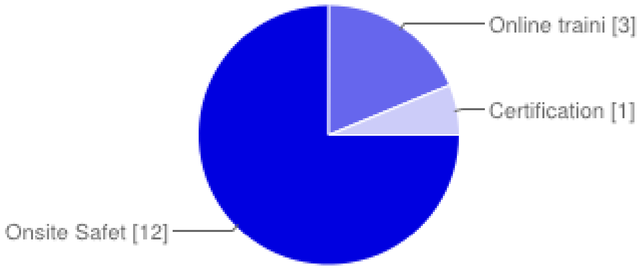


Good Safety leadership abilities in Site Supervisors [Please rate importance of the following factors for the safety programme?



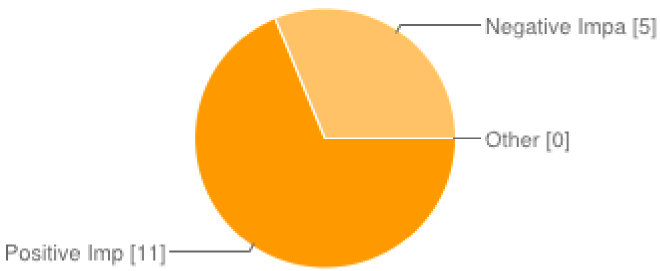
Section 4 Understanding Construction Health and Safety Attitudes and Perceptions

For safety training, what is the most effective method?



Onsite Safety Training and Education	12	75%
Online training	3	19%
Certification Programme for site safety	1	6%

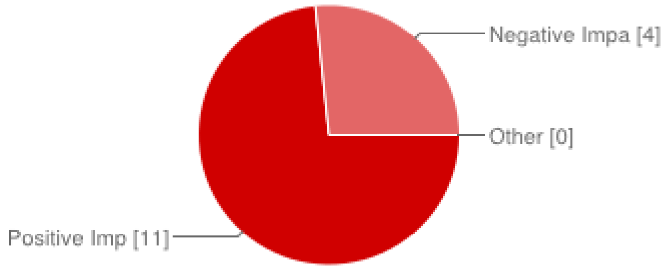
How will investment in safety programme impact project schedule?



Positive Impact	11	69%
Negative Impact	5	31%

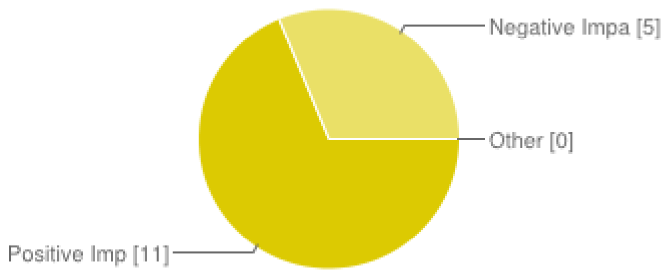
Other	0	0%

How will investment in safety programme impact project budget?



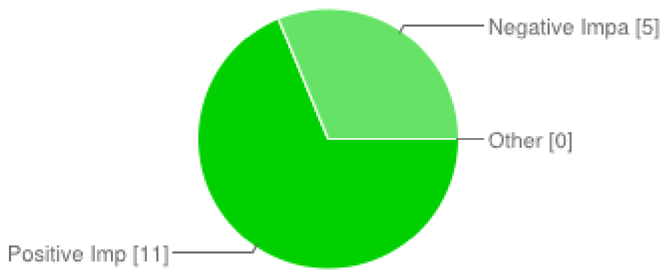
Positive Impact	11	69%
Negative Impact	4	25%
Other	0	0%

How will investment in safety programme impact company‘s profitability?



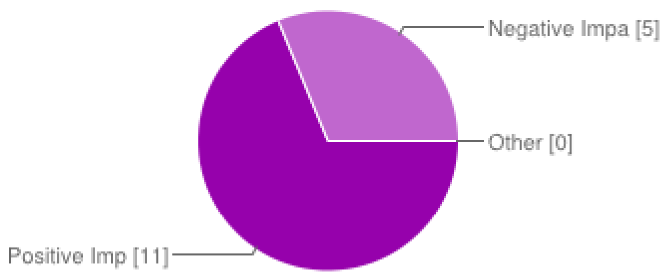
Positive Impact	11	69%
Negative Impact	5	31%
Other	0	0%

How will investment in safety programme impact project quality?



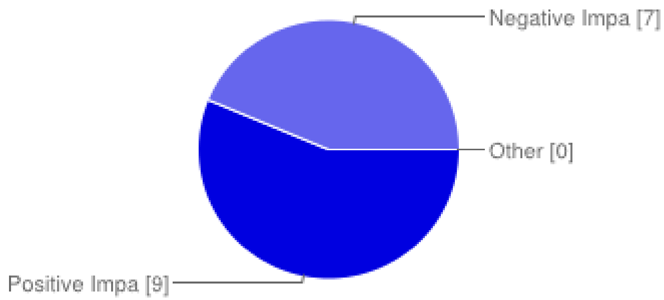
Positive Impact	11	69%
Negative Impact	5	31%
Other	0	0%

How will investment in safety programme impact safety KPIs (e.g. injuries)?



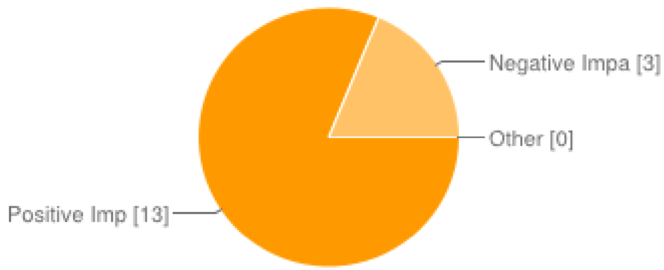
Positive Impact	11	69%
Negative Impact	5	31%
Other	0	0%

How will investment in safety programme impact project quality?



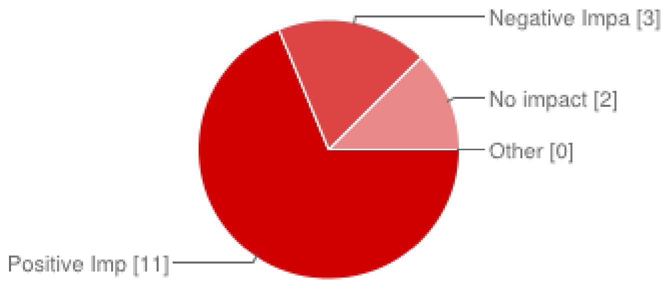
Positive Impact	9	56%
Negative Impact	7	44%
Other	0	0%

What impact earlier involvement of contractors in design and construction stage can make on construction projects?



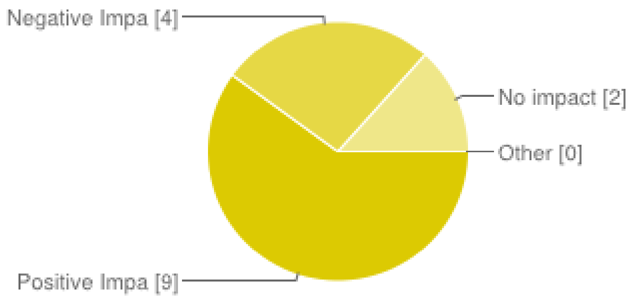
Positive Impact1	3	81%
Negative Impact	3	19%
Other	0	0%

How can BIM Impact on-site construction safety?



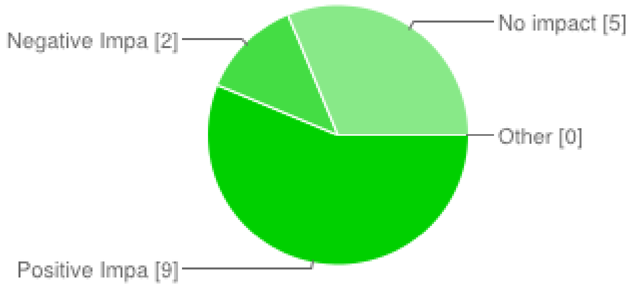
Positive Impact	11	69%
Negative Impact319%		
No impact	2	13%
Other	0	0%

How does use of off-site construction techniques and processes impact construction safety?



Positive Impact	9	56%
Negative Impact	4	25%
No impact	2	13%
Other	0	0%

How does use of mobile tools (e.g. phones, tablets) could impact construction safety?



Positive Impact	9	56%
Negative Impact	2	13%
No impact	5	31%
Other	0	

Appendix 4: Interview Questions

Semi-structured interview Guide: for business owners and managers

Introduction / Preliminaries

Thank you for agreeing to be interviewed.

My name is (Yahya Balgheeth) and as you may be aware the purpose of the study is to explore the views of business owners and managers about BIM and health and safety in Saudi Arabia.

It is hoped that the research will improve health and safety in Saudi Arabia.

You are being asked to participate because you are a business owner or manager in Saudi Arabia.

There is no obligation to take part - it is entirely voluntary. If you decide to participate you are still free to withdraw at any time.

This interview will last around (give an estimated time – e.g. 30-45 minutes).

The confidentiality of your responses is guaranteed by the researchers and your identity will not be revealed at any time. When the research is presented in a report it will not be possible for anyone to tell whether you participated in the research or what your views were.

Any data you provide in this interview will be stored securely.

Section A: Information about the participant

Your area of work:
Public sector.
Consultants.
Contractor.
Other, specify:

Your area of specialisation:
Engineering

Architecture

Management

Other, specify:

Your highest educational level:

Bachelor

Higher Diploma

Master

PHD

Section B: Health and Safety in the private sector

I would like to start by asking you some questions regarding Health and safety in the private construction sector in Saudi Arabia generally. I will then move onto more specific questions about you and your organisation

What are the greatest challenges in construction health and safety for private sector construction contractors in KSA?

Do you think that having a multicultural and multilingual workforce in Saudi Arabia has any implications for the management of health and safety?

- If YES, please say what these are

- Please say how these implications can best be managed so that health and safety is not compromised in any way

Do you feel that engineers working on construction sites in Saudi Arabia have an adequate level of qualification and experience in engineering?

If No – what other training, qualification or experience do you think is necessary?

Section C: Your organisation and Health and Safety in KSA

How would you describe the legal requirements for health and safety on construction / building sites in Saudi Arabia?

How do you manage the health and safety aspects of your works?

What are the major challenges, which your business faces, in enforcing health and safety standards on construction sites in KSA?

What are the critical successes factors in Health and Safety practice for your company?

Would you say that you have a multicultural and multilingual workforce?

(if Yes:)

How many nationalities are working in the organisation?
How many formal languages are used in within the organisation?
Are there any people in your workforce that are not fluent in Arabic?

(For those who do have a multicultural / multilingual workforce):

Does having a multicultural or multilingual workforce have implications for internal or external communications in your organisation?

What do you think are the most important ways to ensure health and safety on construction / building sites?

Are you familiar with the principles of health and safety legislation in Saudi Arabia?
If "yes", please say what you think the main principles of the legislation are

Do you have a Director of Health & Safety or someone leading on health and safety at senior management / Board level?

Do you train your workers in health and safety?
If yes, please describe the health and safety training which you provide – what topics does it cover, how long does it take to deliver, how do you deliver it (e.g. e-learning or face to face); do you test workers on their health and safety skills/knowledge; are their inspections on site to assess the extent to which health and safety procedures are carried out?

What are your company's motivations for promoting/enforcing health and safety?

Can you please describe your accident statistics over the last five years?

Number of injuries / fatalities
Trend – increasing or decreasing
Why do they think stats are increasing / decreasing / staying the same

What are the drivers for your organization to improve health and safety on construction sites which your company works on?

Does it give reduction in costs? Decreased insurance premiums? Give better chances in tendering? Reduce staff turnover?

What lessons, if any, have you learnt about improving their health and safety on construction sites, which your company works on?

Section D: Awareness of BIM and whether it can enhance Health and Safety on construction site?

Explain briefly about BIM, then Ask :

Have you heard about BIM?

Prior to this interview, has your organisation used BIM?

If YES – ask them to name particular programmes and their general impression of BIM, how they have used it, has BIM been used in relation to health and safety

Do you think BIM could be used by your organisation or (if already used) used more frequently?

BIM has the potential to check for compliance to regulation on health and safety risk. Do you consider the integration of BIM into building regulation a positive development to the management of health and safety?

Do you consider BIM an important tool for site induction?

Do you consider BIM an important tool for site induction with particular regard to linguistic or cultural diversity in the workforce?

Do you think BIM will enhance Health and Safety in your organization?

Why?

Section E: Safety management practices - implemented and perceptions by Saudi Contractors?

In your view, Are safety management practices being implemented by Saudi Contractors?

If YES, is this being done in full / in part, slowly / rapidly, what are the problems in implementation in their view

In your view, how are safety management practices perceived by Saudi Contractors?

Section F: Closing the interview

Thank you so much for your co-operation. Before we finish, is there anything else that you would like to say or anything, which you would like to ask me?

(If not – thank you).

Appendix 5: Manual Coding by Colour

H

Section A: Information about the participant

Your area of work:

Public sector.

Consultants.

Contractor.

Other, specify:

Your area of specialisation:

Engineering

Architecture

Management

Other, specify:

Your highest educational level:

Bachelor

Higher Diploma

Master

PHD

What are the greatest challenges in construction health and safety for construction sector in KSA?

The Construction Market in Saudi Arabia is a huge flourishing market and the government with the aim to encourage progress spends $100 billions in this sector. These incentives attract large, medium and small companies to this sector. These companies are mainly concerned about the profit of the projects rather than the quality of the tasks.

This leads them to look for cheap and unqualified workforce from poor countries where there is no concern about the wellbeing of their workforce. Consequently these workers are distanced from the culture of health and safety regulations.

Also the other important issue which affects the health of the workers is the weather condition of the country. The companies ask the workers to work at temperatures above 50 degrees centigrade, despite the fact that the government has prohibited work at these temperatures. Regrettably the companies force their workforce to do so.

Do you think that having a multicultural and multilingual workforce in Saudi Arabia has any implications for the management of health and safety?

- If YES, please say what these are

- Please say how these implications can best be managed so that health and safety is not compromised in any way

The differences in culture and language work as a barrier for the workers to communicate with each other and have a negative impact on observance of health and safety regulations on the project site. The workers come from various countries such as India, Pakistan, Seri Lanka, Yemen and Egypt. Unfortunately cooperation between them is poor and this issue results in the increase of accident rates.

In particular, the number of accidents was very high this year and all of the victims were from countries that I mentioned Therefore we need to elevate the level of their knowledge by implementing training courses so that they learn to prioritize health and safety enabling them to save their own lives in the workplace.

Do you feel that engineers working on construction sites in Saudi Arabia have an adequate level of qualification and experience in engineering?

If No – what other training, qualification or experience do you think is necessary?

The engineers working in the construction sector are mainly from outside Saudi Arabia. Some of them are qualified and experienced in their profession and have passed various training course in the field of health and safety. Regretfully there are some who possess fake educational certificates. Therefore they have no experience what so ever in health and safety matters. Naturally this issue escalates the rate of accidents and results in delay and cancelation of projects.

It is essential to check the authenticity of the documents provided by the engineers. Also conducting periodical training courses for engineers will help to elevate their expertise and quality of work at the project sites.

4. How would you describe the legal requirements for health and safety on construction / building sites in Saudi Arabia?

The government has implemented health and safety indicators for all companies to conform. Unfortunately there is a serious concern on how to make sure that companies are bounded to implement these regulations. We come across companies which pay no attention to health and safety issues. There are many examples such as the collapse of the dome of Ghasim University and the downfall of the crane during the pilgrimage last year. All of these are due to negligence of safety regulations by the companies.

5. How do you manage the health and safety aspects of your works?

We have stringent procedures in our company to safeguard health and safety. The project manager is the first person responsible for this matter. At the event of any accident first he would be held accountable. As the result we witness that he is very strict in ensuring that every one implements the regulations. As we are a Chinese company, most of our workers come from China and countries where they speak English; therefore we can not render the difficulty of communication as a problem.

What are the major challenges, which your business faces, in enforcing health and safety standards on construction sites in KSA?

The only challenge that our company faces is to adapt our workers with the climate here in Saudi Arabia. The high temperature is the cause of many serious accidents because our workers are not used to work in such a climate. Wearing a special suit, safety hat and boots in temperatures above 50 degree that sometimes 60 is very demanding.

Which of these do you consider responsible for health and safety issues on construction site?

Would you say that you have a multicultural and multilingual workforce?

(If Yes :)

How many nationalities are working in the organisation?

How many formal languages are used in within the organisation?

Are there any people in your workforce that are not fluent in Arabic?

We are a Chinese company that has worked in Saudi Arabia for a long time and we have been involved in building canals and bridges. 65% of our workers come from China and the rest are from East Asia, Middle East and India.

Three different languages are spoken in our project sites. But the main language used is English.

Does having a multicultural or multilingual workforce have implications for internal or external communications in your organisation?

Despite the importance of the variety of languages in the workplace this is not considered as a problem in our company. Since we are an international company and engaged in different countries, it has been our policy to lower the variety of nationality in our workforce.

By this policy we have decreased the negative impacts created by the diversity of languages and cultures causing discord between the workers.

What do you think are the most important ways to ensure health and safety on construction / building sites?

The most important issue to ensure the implementation of health and safety is to compile a weekly report in regards to each of the workers. This report is an assessment of the worker's compliance with the safety regulations. The report will give marks from 1 to 10 and if a worker obtains 6 he will be called for a disciplinary meeting and if this continuous, part of his wage will be deducted as a fine.

Are you familiar with the principles of health and safety legislation in Saudi Arabia? If "yes", please say what you think the main principles of the legislation are

Yes, I am aware of the principles and regulations of health and safety in the country. The most important of all is the company's responsibility towards the workers" livelihood. In the occurrence of an accident or death of a worker or any other problem, the company will compensate worker's family.

Do you have a Director of Health & Safety or someone leading on health and safety at senior management / Board level?

We have a safety officer who will supervise the workers and ensures that they comply with the safety regulations. He would report his observations to the project manager who is the first person responsible for health and safety.

Do you train your workers in health and safety?

In fact we do train our workers. We publish books, bulletins and erect educational billboards to highlight the importance of health and safety.

What are your company's motivations for promoting/enforcing health and safety?

Indeed, our main motivation is to safeguard the health and safety of our workforce. They are the fundamental factor in completion of a project according to the timetable. This issue guarantees the continuation of our operation in the Saudi market and increases the trust of our clients in the competency of the company. The consequence would be our success in the region and increase value of our shares as an international company.

Can you please describe your accident statistics over the last five years?
In our company like others, accidents do happen. However I don"t have precise statistics of deaths and injuries, but the numbers are not high. The losses of lives were not more than fifteen and the number of injuries may reach about 125 during the past 5 years.

What are the drivers for your organization to improve health and safety on construction sites which your company works on?

Does it give reduction in costs? Decreased insurance premiums? Give better chances in tendering? Reduce staff turnover?
In fact, our company looks at health and safety as an important issue in any project. Therefore we make great effort to prioritize safety like other international companies in the developed countries such as the USA or UK which have great concern about safety.

Hence we are in constant contact with our partners in other countries and with our mother company in China in order to acquire the latest measures to ensure safety in the workplace. As you know, our company is pursuing profit, therefore finishing a project without any accidents results in the continuous flow of work without interruption, this in turn means completion of the project on time. Result: more profit and more trust building.

Section D: Awareness of BIM and whether it can enhance Health and Safety on construction site?

Have you heard about BIM?
BIM, yes; I have heard about it but my knowledge on it is very limited.

Prior to this interview, has your organisation used BIM?

So far it has not been used but we will consider it seriously since it has a direct impact

on progress of the job, reduction of time and lowering the number of mistakes. It will also connect the company to a system that would make the execution of the job easier and ensures the progress of the project.

Do you think BIM could be used by your organisation or (if already used) used more frequently?

Yes, it will be brought to use soon.

BIM has the potential to check for compliance to regulation on health and safety risk. Do you consider the integration of BIM into building regulation (BIM4regs) a positive development to the management of health and safety?

Surly that would have positive impact on health and safety, so despite my limited knowledge I am in favour of implementing it. However I have seen a number of video clips on U-tube which show that using this system reduces the number of accidents prior to the start of the project because it specifies the accident sensitive areas, and enables the workforce to be informed before –hand.

Do you consider BIM an important tool for site induction?
Yes, it is an important tool despite the fact that I have limited knowledge about it.

Do you consider BIM an important tool for site induction with particular regard to linguistic or cultural diversity in the workforce?
Yes, what I mean is that it will help to ease communication with everyone, in particular in regards to delivery of the daily instructions to the workers in their own language. Also it offers you to see all the stages of the project beforehand. This will give a clear overview to the entire workforce about the project from start up to finish.

Do you think BIM will enhance Health and Safety in your organization?

Yes, it will enhance health and safety and I will give it the score of 4 out of 5. Because it diagnoses the problems and attempts to solve them in later stages in a way that it would result in development of health and safety.

Appendix 6: Publications from the PhD Study

Proceedings of the Global Conference on Engineering and Technology Management 2014 Istanbul, Turkey, June 23–26, 2014

Enhancing Health & Safety Management in Construction Sites by Using Mobile Computing in Saudi Arabia

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Abstract
This paper investigates the relevance of mobile computing to improve Health and Safety (H&S) in onsite construction projects. Even though the construction sector in Saudi Arabia has been rapidly expanding, the health and safety record of this industry remains considerably poor given the rising figures of injuries and mortalities.The literature review identifies and highlights the current status of H&S practice in Saudi construction projects and the reasons behind it. Moreover, the review also indicates and discusses the proposed scenario of using mobile computing technology to improve H&S. From this, the paper discusses the relevance of mobile computing for better information provisioning, information flow and decision making. Conclusions are drawn about the future impact of emerging mobile computing technologies to enhance H&S in construction site.

Keywords
Health and Safety, Construction Management, Communication, Mobile computing.